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OPERATION SUN BEAM, SHOTS LITTLE FELLER I, II, JOHNIE BOY, AND SMALL BOY

Project Officers Report—Project 2.8

Radiological Surveys

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POR-2266

Operation
SUN BEAM
SHOTS LITTLE FELLER I, II, JOHNIE BOY, AND SMALL BOY(u)

PROJECT OFFICERS REPORT—PROJECT 2.8

RADIOLOGICAL SURVEYS (U)

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Issuance Date: October 30, 1964

OPERATION SUN BEAM

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ABSTRACT

The objectives of Project 2.8 were (1) to determine the residual radiation patterns and the field decay rates resulting from low-yield contaminating detonations, and (2) to determine the gamma dose rates and decay rates in and around the crater areas as soon after detonation as possible.

Detailed ground surveys of the contaminated areas were conducted in July 1962 at the Nevada Test Site (NTS) after the detonations of Little Feller I, Little Feller II, Johnie Boy, and Small Boy. In addition to ground-survey operations, high-level dose-rate recorders were placed by helicopters in or near the crater produced by each shot, and helicopter-to-ground instruments were used to measure dose rates in ground zero areas.

Approximately three thousand film badges were installed at on-site monitoring points for the four shots, and about four thousand badges were placed at off-site survey points to 300 miles for the Small Boy shot.

The H+1-hour gamma dose-rate contours for the Little Feller I and II, Johnie Boy, and Small Boy shots are based on ground surveys that were significantly more detailed than surveys at any previous nuclear tests.

Field gamma dose-rate decays through D+1 day varied considerably from point to point within individual patterns. In general, for the

above-ground shots, there were differences between the decay rates near ground zero and those observed in the downwind direction. In the expression $I_t = I_1 t^{-x}$, the average exponent in the upwind and crosswind directions tended to be appreciably less than 1.2; for stations at significant downwind distances, the decay exponent tended to be near 1.2.

The maximum ground zero dose rates based on measurements extrapolated to H+1 hour ranged from 3,300 r/hr for the Little Feller shots to 38,000 r/hr for Small Boy.

The percent of total activity deposited by Little Feller I, Little Feller II, and Small Boy within the 0.5 r/hr H+1-hour contour was 6.5 percent, 6.6 percent, and 24 percent, respectively. The percent deposited within the Johnie Boy 1 r/hr H+1-hour contour was 69 percent.

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The objectives of this project were: (1) to determine the residual radiation patterns and the field decay rates resulting from low-yield contaminating detonations, and (2) to determine the gamma dose rates and decay rates in and around the crater areas as soon after detonation as possible.

1.2 BACKGROUND

Knowledge of the residual contamination from bursts of tactical nuclear weapons on or near the surface is required to exploit more effectively the offensive use of these weapons and to prepare the necessary countermeasures for defense against them. The input information now available for the current prediction systems is based on limited data from a few test detonations.

The land surface shots for which close-in fallout contamination intensities have been measured are: the surface shot of Operation Jangle (1.2 kt); Coulomb C of Operation Plumbbob (500 tons); Fig of Operation Hardtack

The H+1-hour downwind dose-rate contour distances for Jangle S, Coulomb C, and Fig are shown in Figure 1.1 as corrected for a 15-knot mean wind speed. This correction was made by assuming that downwind distance for a given contour varies as the cube root of the wind speed (Reference 2).

The determination of the fallout pattern resulting from the Jangle surface shot was of necessity exploratory in nature and was also, in many respects, a dry run for the subsequent underground shot. The fallout pattern that was developed was incomplete. The overall downwind extent of the contours of importance in scaling or extrapolation to higher yields was not determined. Therefore, the extent of contours representing dose rates less than 35 r/hr at H+1 hour is not known.

For Coulomb C, a one-point detonation, the 1, 10, and 100 r/hr contours were relatively well defined (Reference 3). The 1-r/hr contour extended approximately 13,000 yards downwind. The mean wind speed for the altitude interval of importance for this shot was estimated to be 8 knots.

The Shot Fig downwind fallout occurred over water. Hence, the equivalent gamma dose rates were inferred primarily from fallout collector data supplemented by monitor readings on a few barges (Reference 4). The 1-r/hr contour for this shot extended 750 yards downwind.

An analysis of Shot Fig results points out that the extent of the 10 r/hr H+1-hour contour for a 20-ton weapon was shorter by a factor of 5 than an admittedly large-range extrapolation from TM 23-200 (Reference 6) would indicate. However, this same analysis showed the extent of the higher level contours (100 r/hr or greater) to be approximately as predicted.

CHAPTER 2

PROCEDURE

This project participated in Shots Little Feller II, Johnie Boy, Small Boy, and Little Feller I, as shown in Table 2.1.

TABLE 2.1 PROJECT 2.8 SHOT PARTICIPATION

Event	Date	Time
	1962	
Little Feller II	7 July	1200
Johnie Boy	11 July	0945
Small Boy	14 July	1130
Little Feller I	17 July	1000

2.1 OPERATIONS

The contaminated area produced by each event was thoroughly surveyed by ground-survey parties and helicopter-to-ground units. In addition, high-dose-rate recording instruments were placed in and near the crater produced by each shot. Film badges were placed throughout the regions of expected fallout.

2.1.1 Ground-Survey Station Layout. In order to accomplish the detailed radiological surveys required to meet the project objectives, it was necessary to establish an array of points throughout the expected downwind region at which the radiation could be measured repeatedly.

CHAPTER 3

RESULTS

3.1 LITTLE FELLER II

Little Feller II was detonated in Area 18 of NTS at 1200 hours PDT, 7 July 1962 The weapon was suspended between two posts with its center of gravity 3 feet above the ground surface. The elevation of surface zero was 5,129 feet. Air temperature at the surface was 35.5°C, and the relative humidity was too low to measure. The upper wind data are shown in Table 3.1. The Little Feller II cloud at H+30 seconds is shown in Figure 3.1. The cloud top reached a height of approximately 11,000 feet MSL (Reference 13).

TABLE 3.1 LITTLE FELLER II UPPER WIND DATA

Observations Made at Forward Control Point, Area 18, at 1200 hours (PDT), 7 July 1962

Height (MSL)	Direction	Speed	Height (MSL)	Direction	Speed
feet	degrees	knots	feet	degrees	knots
Surface	171	7	12,000	120	13
6,000	190	14	13,000	110	19
7,000	180	17	14,000	100	15
8,000	180	13	15,000	90	9
9,000	180	10	16,000	140	3
10,000	180	10	17,000	200	7
11,000	140	7	18,000	200	[illegible]

3.1.1 Field Decay Rates.

The radiological survey of the Little Feller II on-site station array was begun 1/2 hour after the detonation.

A second HILEM-2R did not operate. The data obtained are listed in Table 3.3.

TABLE 3.3 GROUND ZERO AREA DOSE RATES FOR LITTLE FELLER II

Location of Instrument	Time After Detonation	Dose Rate Reading	Dose Rate Extrapolated to H+1 Hour	Type of Instrument
	hours	r/hr	r/hr	
30 ft NW of GZ	1.0	300	300	HILEM-2R Recorder
Center of Crater	1.3	3,500	4,800	Dropping Probe
25 ft NE of GZ	4.7	60	260	Dropping Probe
25 ft W of GZ	4.7	100	440	Dropping Probe
20 ft SW of GZ	4.8	94	420	Dropping Probe
Vicinity of Crater	21.3	6.9	92	Dropping Probe
Center of Crater	285.7	1.0	-	Dropping Probe
Center of Crater	456	1.5	-	Ground Survey
20 ft N of Crater	456	0.3	-	Ground Survey
20 ft E of Crater	456	1.0	-	Ground Survey
20 ft S of Crater	456	0.12	-	Ground Survey
20 ft W of Crater	456	0.4	-	Ground Survey

The dose-rate recorder was placed about 30 feet northwest of the crater at H+50 minutes and was recovered on D+9 days. The dose rates decreased to the threshold value of the instrument, about 1 r/hr, after H+60 hours. The recorder data were corrected for chart speed and dose-rate calibrations and are presented in Figure 3.10. The average decay slope of the curve from 1 hour to 20 hours is less than 1 and is consistent with decay exponents calculated from the close-in, ground-survey data. The H+1-hour dose rate indicated by this instrument is 300 r/hr.

The early dropping-probe data were corrected by calibration curves and converted to H+1 hour by the decay curve in Figure 3.10. Approximate

The total-dose contours presented in Figure 3.12 were constructed primarily on the basis of the ELRDL film data. In a few instances where gaps existed at doses less than 200 r, REECo values were multiplied by 1.4 and used for locating the position of the contours. Approximately 275 ELRDL values and 20 REECo values were used in constructing the total-dose contours. These film data are presented in Appendix B. For stations shown in Figure 2.1 it may be noted that the high total-dose contours around ground zero are relatively larger and more nearly circular than are the dose-rate contours shown in Figure 3.7. This was to be expected since the films at the close-in stations were exposed to both initial and residual radiation.

3.2 JOHNIE BOY

The Johnie Boy shot was fired in Area 18 of NTS at 0945 PDT, 11 July 1962, and produced a yield of 0.5 ±0.2 kt. The weapon was buried with its center of gravity 23 inches below the ground surface. The elevation of surface zero was 5,153 feet. Air temperature at the surface was 24.3°C and the relative humidity was 12 percent. The upper wind data are shown in Table 3.4. The Johnie Boy cloud at H+25 seconds is shown in Figure 3.13. The cloud top reached a height of 17,000 feet MSL (Reference 13).

TABLE 3.4 JOHNIE BOY UPPER WIND DATA

Observations made at Forward Control Point, Area 18, at 0945 hours (PDT), 11 July 1962

Height (MSL)	Direction	Speed	Height (MSL)	Direction	Speed
feet	degrees	knots	feet	degrees	knots
Surface	195	7	13,000	190	17
6,000	170	7	14,000	200	21
7,000	160	7	15,000	200	22
8,000	160	11	16,000	200	22
9,000	160	16	17,000	200	27
10,000	170	15	18,000	200	27
11,000	180	12	19,000	210	26
12,000	180	15	20,000	200	23

3.2.1 Field Decay Rates. The Johnie Boy detonation was followed by comprehensive radiological surveys of the on-site and off-site areas. The survey station locations are shown in Figures 2.1 and 2.2. All survey data are reported in Appendix C for station locations presented in Figures 2.1 and 2.2. Although the surveys were begun within H+1/2 hour, many stations were not monitored until several hours had elapsed and some were not monitored for several days. An analysis of field gamma decay rates was required in order that H+1-hour values could be calculated.

Of the data available, that useful for decay purposes is limited to the on-site area. Figures 3.14 and 3.15 typify the information recorded from many selected points on the station network. It is evident that the decay relationship, expressed in Equation 3.1, with a constant decay

TABLE 3.5 GROUND ZERO AREA DOSE RATES FOR JOHNIE BOY

Location	Type of Measurement	Time After Detonation	Dose-Rate Reading
		hours	r/hr
8° azimuth 90 ft from GZ (30 ft from Crater Lip)	Recorder	5	~ 500
Center of Crater	Dropping Probe	169	10
Inside Crater Lip	Dropping Probe	192	0.5
WNW Crater Lip	Ground Survey[a]	243	1.0
2/3 of distance to Bottom	Ground Survey[a]	243	0.8
Crater Bottom	Ground Survey[a]	243	1.5
1/3 of distance to SSE Top	Ground Survey[a]	243	0.95
2/3 of distance to SSE Top	Ground Survey[a]	243	1.1
SSE Top	Ground Survey[a]	243	0.7
S Crater Lip	Ground Survey	243	1.0
NW Crater Lip	Ground Survey	243	1.75
N Crater Lip	Ground Survey	294	2.7
40 ft N of N Crater Lip	Ground Survey	294	2.0
Center of Crater	Ground Survey	2,400	1.5
N Lip	Ground Survey	2,400	0.80
20 ft below N Lip	Ground Survey	2,400	0.15
40 ft below N Lip	Ground Survey	2,400	0.20
60 ft below N Lip[b]	Ground Survey	2,400	0.35
E Lip	Ground Survey	2,400	0.85
20 ft below E Lip	Ground Survey	2,400	0.20
40 ft below E Lip	Ground Survey	2,400	0.30
60 ft below E Lip	Ground Survey	2,400	0.90
71 ft below E Lip[c]	Ground Survey	2,400	1.25
S Lip	Ground Survey	2,400	0.19
20 ft below S Lip	Ground Survey	2,400	0.20
40 ft below S Lip	Ground Survey	2,400	0.15
62 ft below S Lip[b]	Ground Survey	2,400	0.75
W Lip	Ground Survey	2,400	0.30
20 ft below W Lip	Ground Survey	2,400	0.12
40 ft below W Lip	Ground Survey	2,400	0.40
60 ft below W Lip	Ground Survey	2,400	0.30
65 ft below W Lip[c]	Ground Survey	2,400	0.90

[a] Dropping probe assembly used as explained in Section 3.2.3

[b] North-south distance across bottom, 28 feet

[c] East-west distance across bottom, 37 feet

The total-dose contours are shown in Figure 3.24. The LSD film data were used where available, and REECo readings, multiplied by the conversion factor 2, were used for readings below 100 r where LSD values were not available. Approximately 190 LSD values and 145 REECo values were used in this manner for constructing the contours. These data are presented in Appendix C for stations shown in Figures 2.1 and 2.2. The effect of the initial radiation on the magnitude of the contours around the ground zero area can be seen by comparing the dose contours with the H+1-hour dose-rate contours shown in Figure 3.20. The dose contours at a given cross-wind distance from ground zero are higher by a factor of at least 100 than those that would be calculated from the dose-rate contours. On the other hand, the very high dose contours immediately downwind of ground zero are lower than those that would be calculated from the dose-rate contours. These lower values may be attributed to the inability of the film used to reliably measure doses higher than a few thousand roentgens.

3.3 LITTLE FELLER I

The Little Feller I shot was fired in Area 18 of NTS at 1000 hours PDT, 17 July 1962, and

was detonated approximately 3 feet above the ground surface. The elevation of surface zero was 5,194 feet. Air temperature at the surface was 29.7°C and the relative humidity was 17 percent. The upper wind data are shown in

Table 3.6. The Little Feller I cloud at H+30 seconds is shown in Figure 3.25. The cloud top reached a height of approximately 11,000 feet MSL (Reference 13).

TABLE 3.6 LITTLE FELLER I UPPER WIND DATA

Observations made at Forward Control Point, Area 18, at 1000 hours, (PDT), 17 July 1962

Height (MSL)	Direction	Speed	Height (MSL)	Direction	Speed
feet	degrees	knots	feet	degrees	knots
Surface	200	15	11,000	140	11
6,000	200	13	12,000	150	13
7,000	190	12	13,000	180	15
8,000	170	12	14,000	180	20
9,000	170	11	15,000	180	23
10,000	150	11	16,000	190	25

3.3.1 Field Decay Rates. No Little Feller I stations were surveyed earlier than H+3.2 hours because of the priority of troop exercises that were conducted in the area of interest (Reference 15). Readings were taken at the majority of the 400 survey stations at approximately H+4 hours and H+26 hours (Appendix D). At approximately 50 of these stations, measurements were also made at H+50 hours, H+74 hours, and H+94 hours. The station layout is shown in Figure 2.1

The ranges and average values of the individual decay exponents based on the two earliest readings along the various stake lines are shown in Table 3.7. These values are shown separately for each half of

TABLE 3.8 GROUND ZERO AREA DOSE RATES FOR LITTLE FELLER I

Location of Instrument	Time After Detonation	Dose Rate Reading	Dose Rate Extrapolated to H+1 Hour	Type of Instrument
	hours	r/hr	r/hr	
Near Crater, E Side	1.67	1,000	1,800[a]	High-level Recorder
Near Crater NNW Side	2.9	200	840[a]	Dropping Probe
WNW of Crater	3.0	118	530[a]	Dropping Probe
Inside Crater Near East Lip	3.0	540	2,400[a]	Dropping Probe
About 60 feet from GZ Azimuth 220°	48	10	1,000[b]	Dropping Probe
Near Crater on NE Lip	48	13	1,400[b]	Dropping Probe
Center of Crater	150	7.5	3,100[b]	Ground Survey
Inner Edge of Crater Perimeter	150	5 to 8	2,000 to 3,000[b]	Ground Survey
Center of Crater	2,260	0.32	-	Ground Survey

[a] Extrapolated from Figure 3.39

[b] Extrapolated by $t^{-1.2}$

The dose contours shown in Figure 3.41 were constructed primarily from the LSD readings. Where necessary, at doses below about 100 r, twice the REECo values were used, as described in Section 3.2.4. Approximately 210 LSD values and 100 REECo values were used in this manner in plotting the contours. The dose data at stations shown in Figure 2.1 are given in Appendix D. The effect of initial radiation on the overall size of the close-in contours relative to the downwind portion of the pattern can be seen by comparing the total dose pattern with the dose-rate pattern shown in Figure 3.37.

3.4 SMALL BOY

The Small Boy shot was detonated in Area 5 (Frenchman Lake) of NTS at 1130 PDT, 14 July 1962

The device was positioned on a wooden tower 10 feet high. The elevation of surface zero was 3,078 feet. Air temperature at the surface was 31.7°C, and the relative humidity was 16 percent. The upper wind data are shown in Table 3.9. The Small Boy cloud at H+20 seconds is shown in Figure 3.42. The cloud top reached a height of approximately 19,000 feet MSL (Reference 13).

3.4.1 On-Site Field Decay Rates. A decay curve was plotted for each survey station at which four or more dose-rate measurements were made. A variety of curve types resulted. Examples are shown in Figures 3.43 to 3.45. There is no clear correlation of location with the types of curve or, for the straight lines, with slope. However, a tabulation of values

TABLE 3.9 SMALL BOY UPPER WIND DATA

(Based on Reference 17)

Observations made at Frenchman Flat. Shot time was 1130 (PDT).

Height (MSL)	1045 PDT (1745Z)		1135 PDT (1835Z)		1145 PDT (1845Z)		1240 PDT (1940Z)	
	Azimuth	Speed	Azimuth	Speed	Azimuth	Speed	Azimuth	Speed
feet	degrees	knots	degrees	knots	degrees	knots	degrees	knots
Surface	-	Calm	135	2	120	2	180	6
4,000	-	Calm	300	1	145	4	185	6
5,000	-	Calm	310	1	170	5	188	7
6,000	203	3	330	2	180	6	212	8
7,000	270	2	280	2	170	6	224	10
8,000	260	5	250	6	180	3	237	10
9,000	235	6	240	12	230	5	245	11
10,000	235	11	240	16	240	11	240	13
12,000	250	9	240	8	235	9	225	8
14,000	240	9	240	8	230	8	280	7
15,000	-	-	-	-	-	-	265	4
16,000	240	7	240	8	230	7	-	-
18,000	270	8	280	14	260	13	-	-
20,000	290	16	280	25	280	23	-	-

of x in the expression,

$$\frac{I_1}{I_2} = \left(\frac{t_2}{t_1}\right)^x \qquad (3.2)$$

for readings on D-day, D+1, and D+2 days indicated a natural differentiation between downwind stations (lines G through W), and crosswind and upwind stations (lines Y and Z). A mean value of $x = 1.27 \pm 0.02$ was computed for the downwind stations by the method of least squares. Nominal dose rates at H+1 hour were then computed by applying the expression,

$$I_1 = I_t t^{1.27} \qquad (3.3)$$

to the earliest measurement available at each downwind station. (In a few instances, where there was reasonable doubt as to the validity of the earliest measurements, a later reading was used).

The same technique failed to provide a satisfactory mean value of x for the Y and Z stations. (The least-squares computation invalidated Equation 3.2). Fortunately, it was possible to construct a composite decay curve normalized to 1 r/hr at H+25.5 hours (Figure 3.46). The earliest reading at each station was extrapolated to H+1 hour along this curve.

The paucity of data made it difficult to characterize decay in Indian Springs Valley and Three Lakes Valley (lines A through F). The single station surveyed on D-day provided a decay curve (Figure 3.47) with a slope of -1.01. A few decay curves beginning on D+1 day

TABLE 3.10 GROUND ZERO AREA DOSE RATES FOR SMALL BOY

Location of Instrument		Time After Shot	Measured Dose Rate	Dose Rate Extrapolated to H+1 Hour	Type of Instrument
Azimuth	Distance from GZ				
degrees	feet	hours	r/hr	r/hr	
SSE	~ 50	3.18	17,300	38,000	High Level Recorder #1
100	~ 50	3.43	3,170	7,200	NRDL GITR II
SSE	~ 50	3.67	3,800	9,000	High Level Recorder #2
ENE	~ 590	5.45	328	1,400	NRDL GITR I
296	~ 20	71.0	25	3,600	Dropping Probe
234	265	71.0	5	700	Dropping Probe
235	80	71.0	19	2,700	Dropping Probe
236	160	71.1	13	1,800	Dropping Probe
284	205	71.1	4	570	Dropping Probe
288	210	71.1	4.5	640	Dropping Probe
293	125	71.1	15	2,100	Dropping Probe
266	300	71.2	5	700	Dropping Probe
267	165	71.2	10	1,400	Dropping Probe
274	305	71.2	4	570	Dropping Probe
282	290	71.2	3	420	Dropping Probe
289	295	71.2	3	420	Dropping Probe
297	275	71.2	0.75	110	Dropping Probe
290	90	71.3	19	2,700	Dropping Probe
Center of Crater		75.0	22	3,300	Dropping Probe
NE	35	75.0	2.5	-	Dropping Probe
W	45	75.0	2.5	-	Dropping Probe
SSE	~ 50	96.6	145	27,000	Dropping Probe
233	310	96.8	15	2,300	Dropping Probe
250	140	96.8	43	8,000	Dropping Probe
280	310	96.9	10	1,800	Dropping Probe
286	310	96.9	3	560	Dropping Probe
235	120	97.0	49	9,100	Dropping Probe
279	275	97.0	13	2,400	Dropping Probe
291	280	97.0	3.5	650	Dropping Probe
Near Center of Crater		119.0	2.0	-	Dropping Probe
At Drum (Figure 3.59) in Crater		406	15	-	Ground Survey

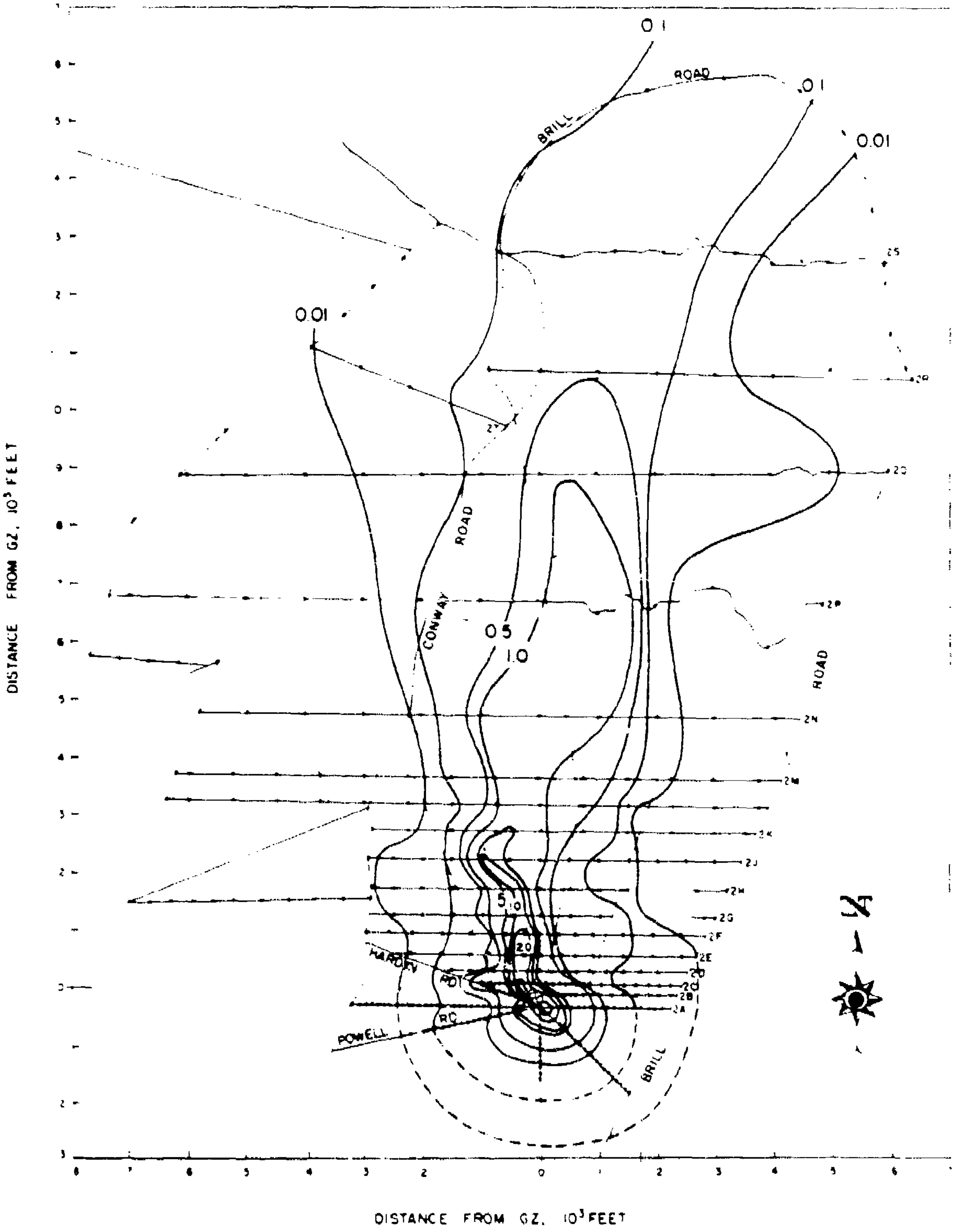

Figure 3.7 Little Feller II dose-rate contours in roentgens per hour at H - 1 hour to 3 miles downwind.

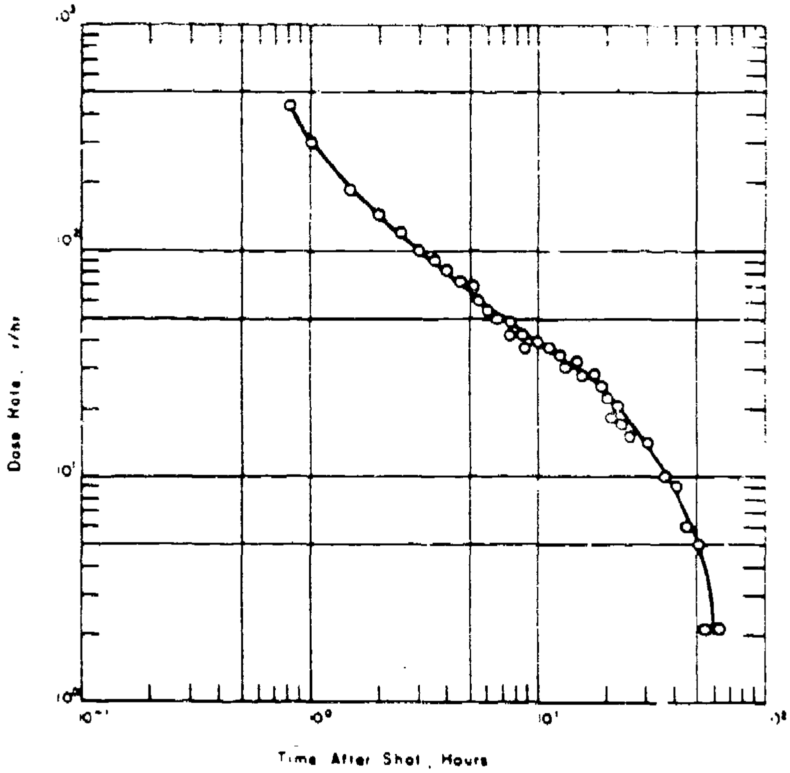

Figure 3.10 Gamma dose-rate decay curve near the Little Feller II crater.

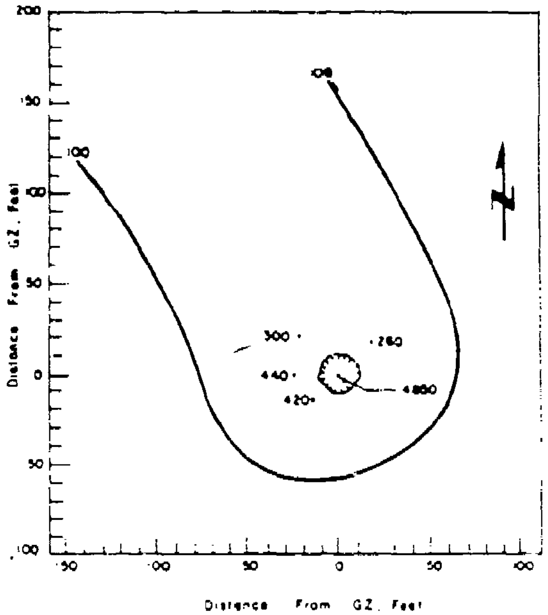

Figure 3.11 Little Feller II ground zero area dose rates in roentgens per hour at H + 1 hour.

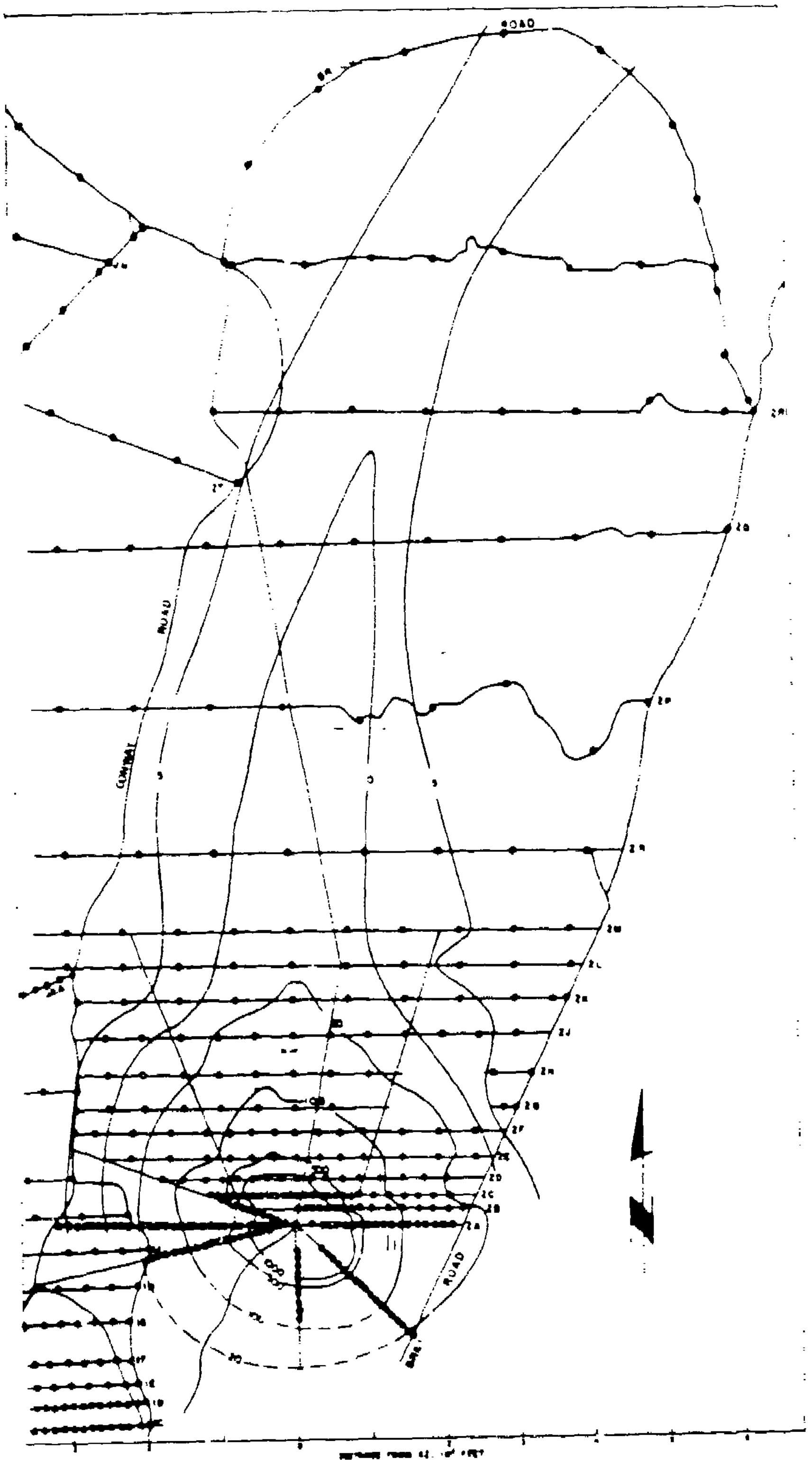

Figure 3.12 Little Feller II 3-day dose contours in roentgens.

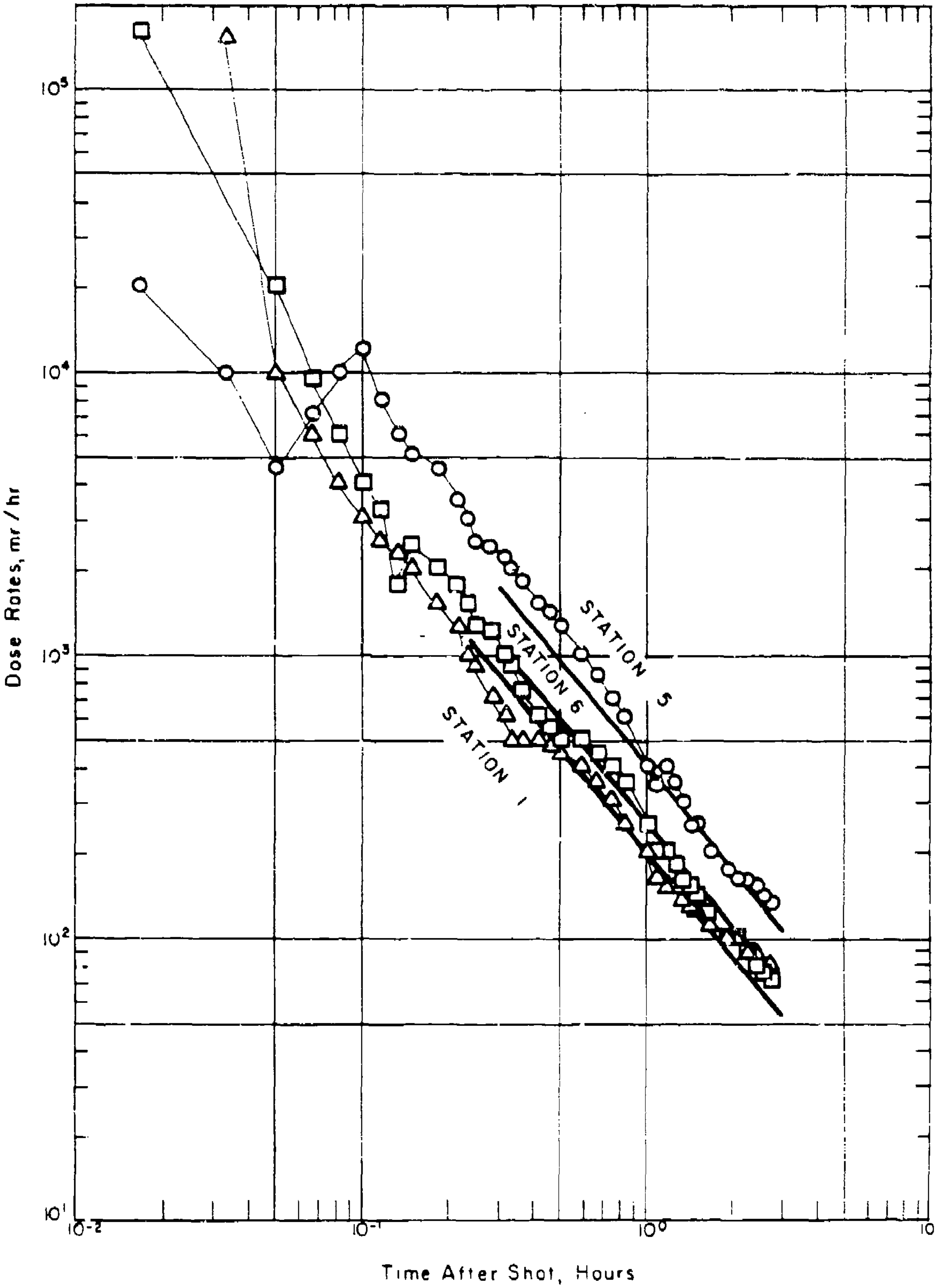

Figure 3.16 Field decay curves for Johnie Boy remote monitoring Stations 1, 5 and 6.

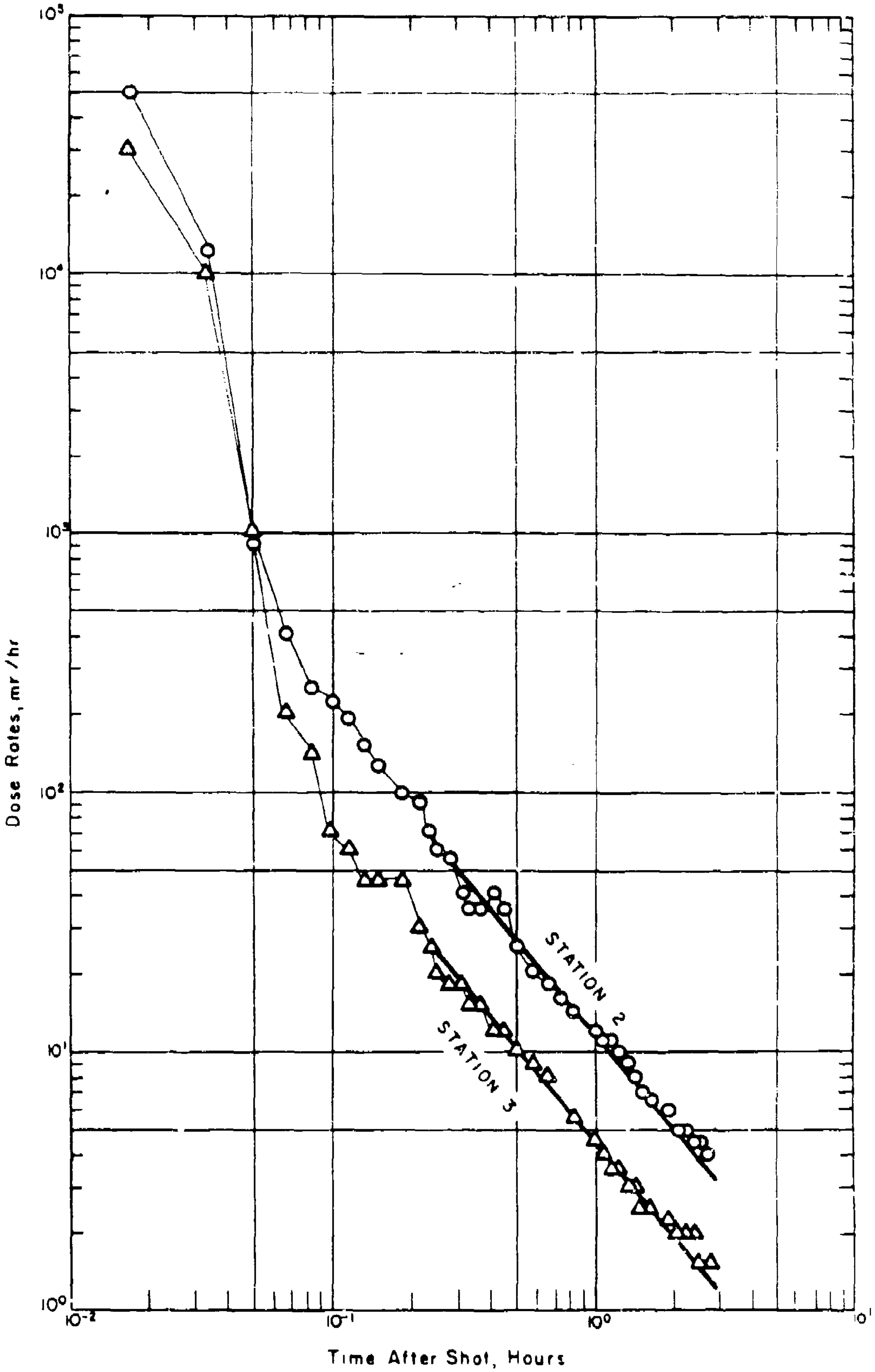

Figure 3.19 Field decay curves for Johnie Boy remote monitoring Stations 2 and 3.

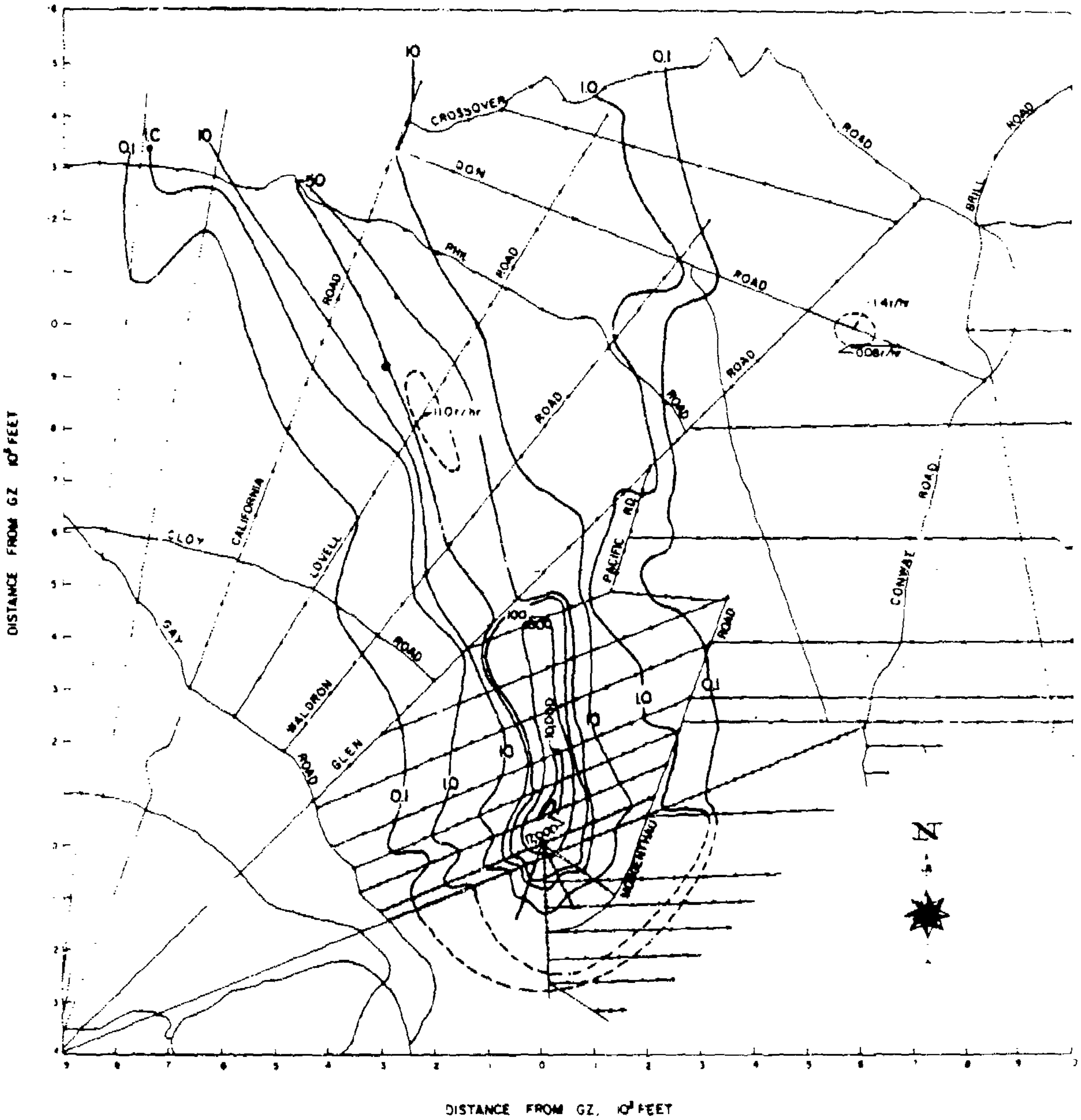

Figure 3.20 Johnie Boy dose-rate contours in roentgens per hour at H +1 hour to 2.5 miles downwind.

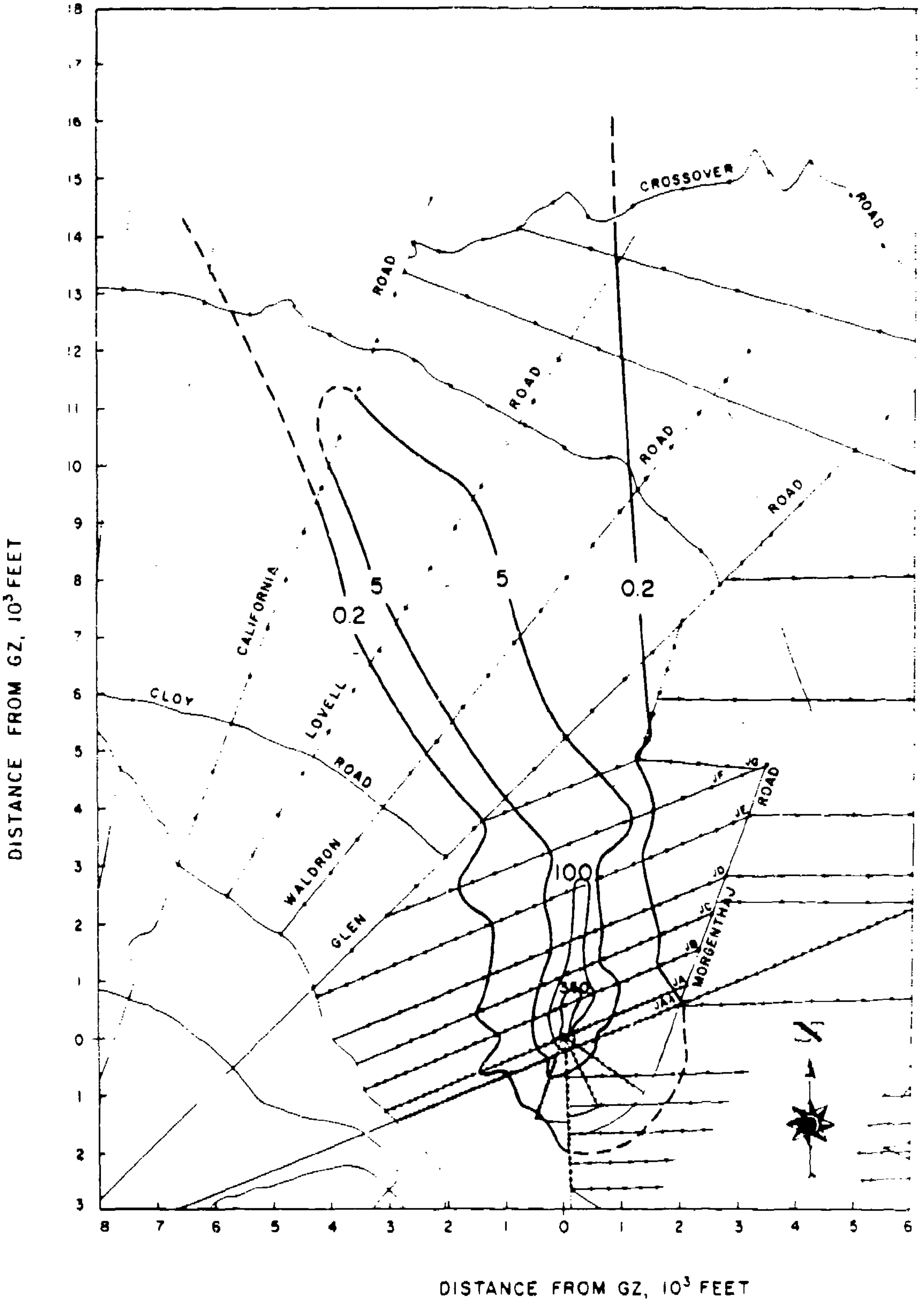

Figure 3.23 Johnie Boy dose-rate contours in milliroentgens per hour at D + 100 days.

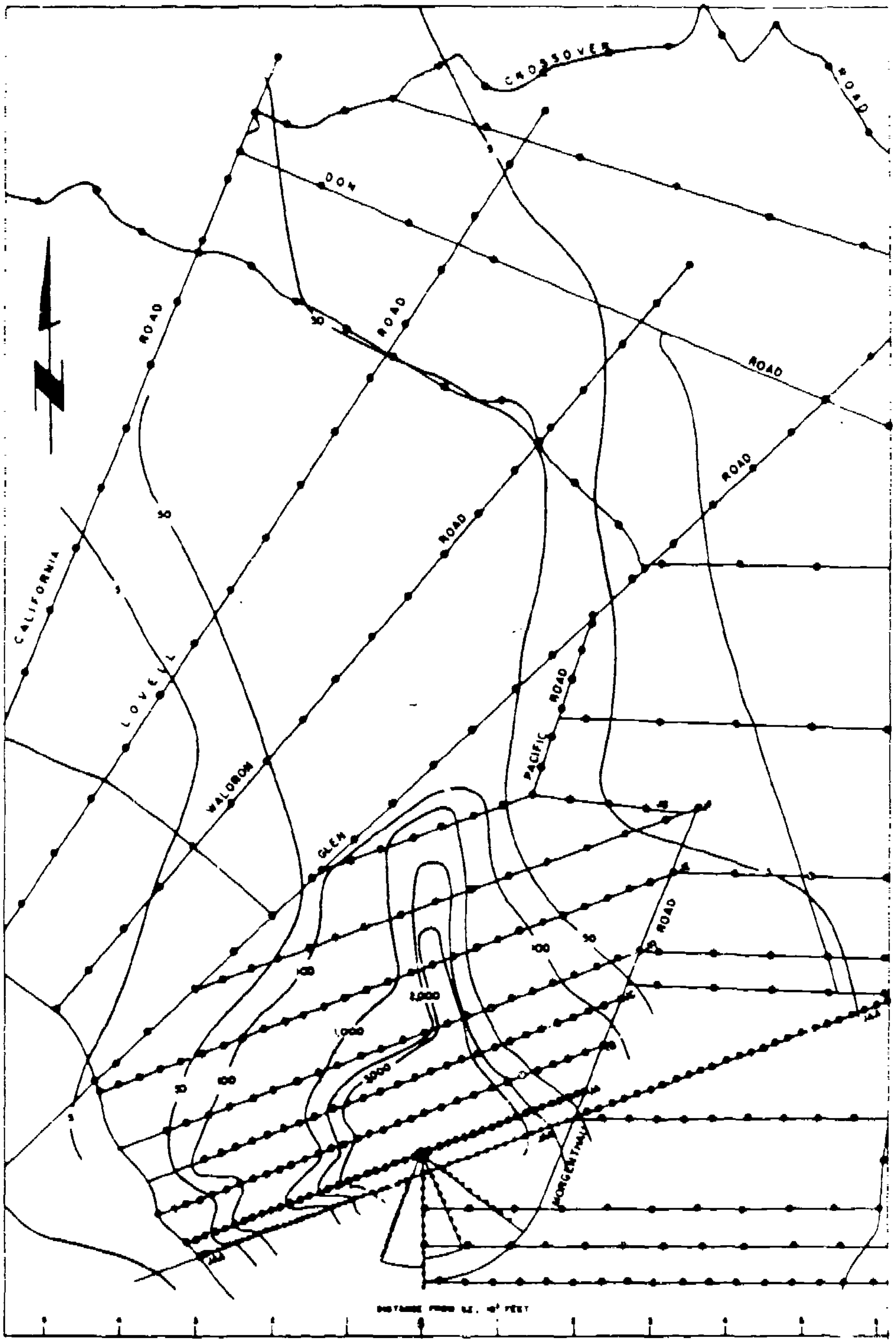

Figure 3.24 Johnie Boy 5-day dose contours in roentgens.

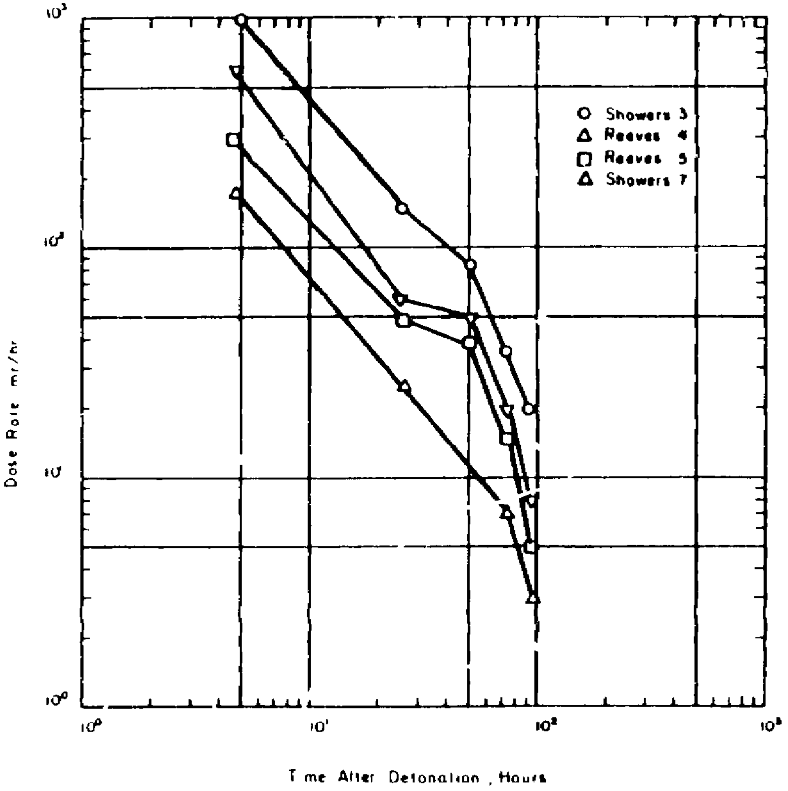

Figure 3.28 Field decay curves for Little Feller I upwind stations

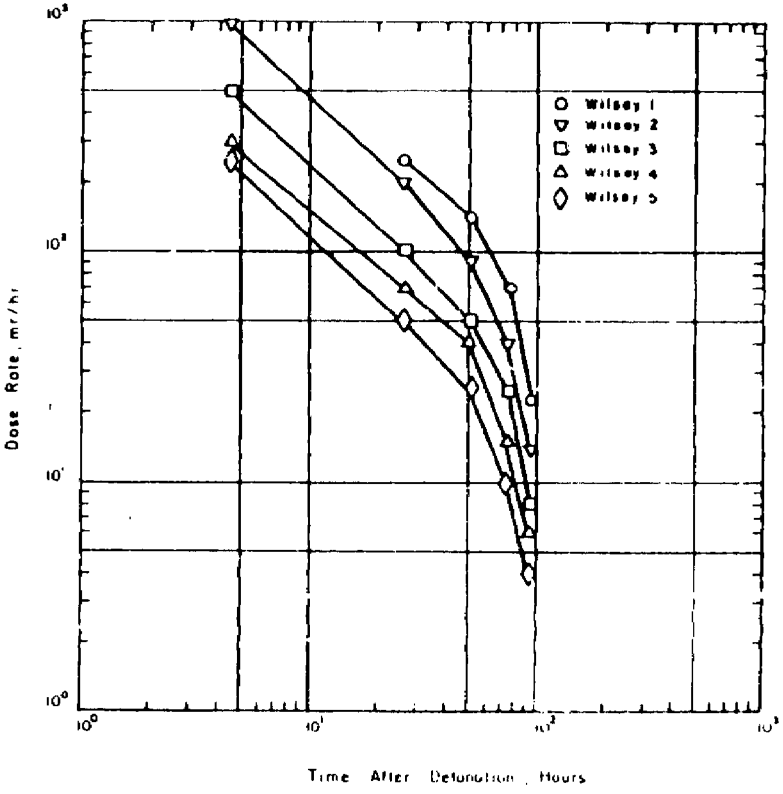

Figure 3.27 Field decay curves for Little Feller I [illegible] stations

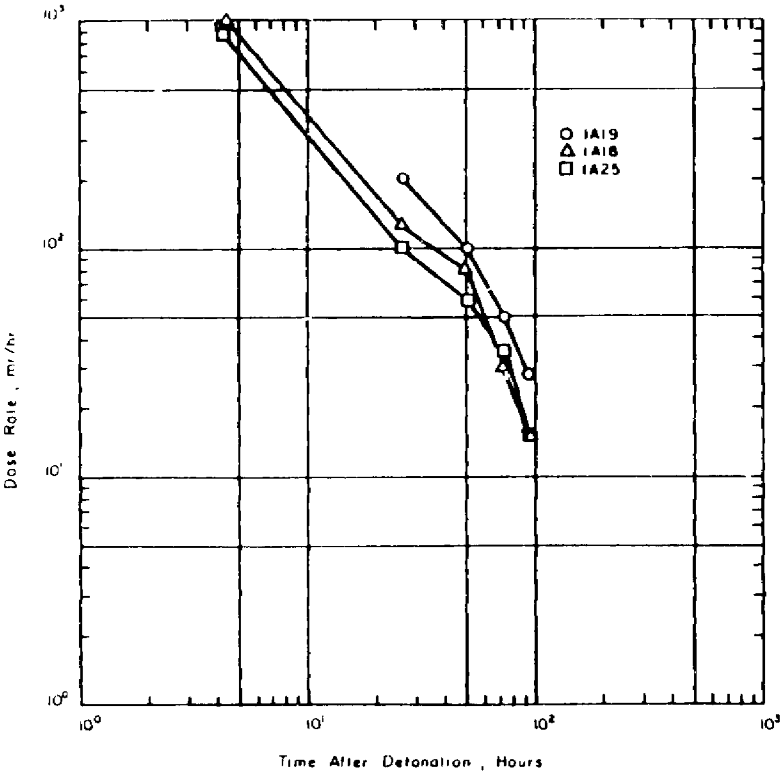

Figure 3.28 Field decay curves for Little Feller I crosswind stations.

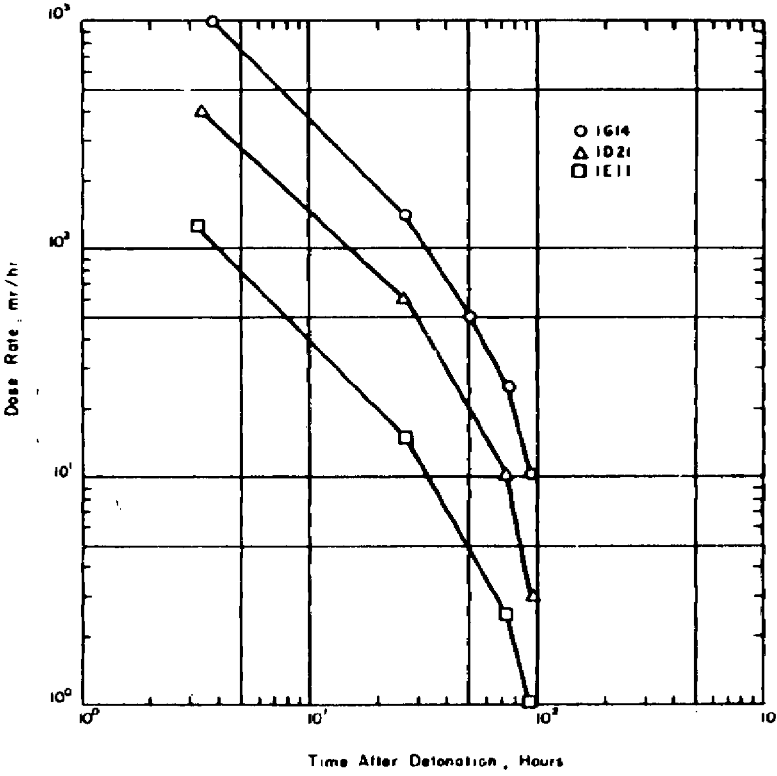

Figure 3.29 Field decay curves for Little Feller I downwind stations

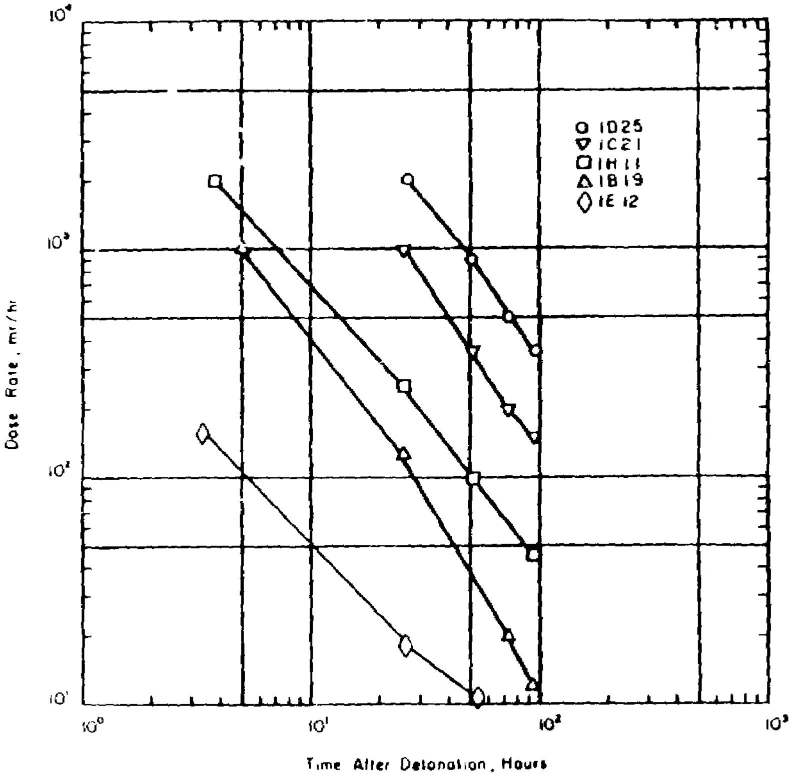

Figure 3.30 Field decay curves for Little Feller I downwind stations.

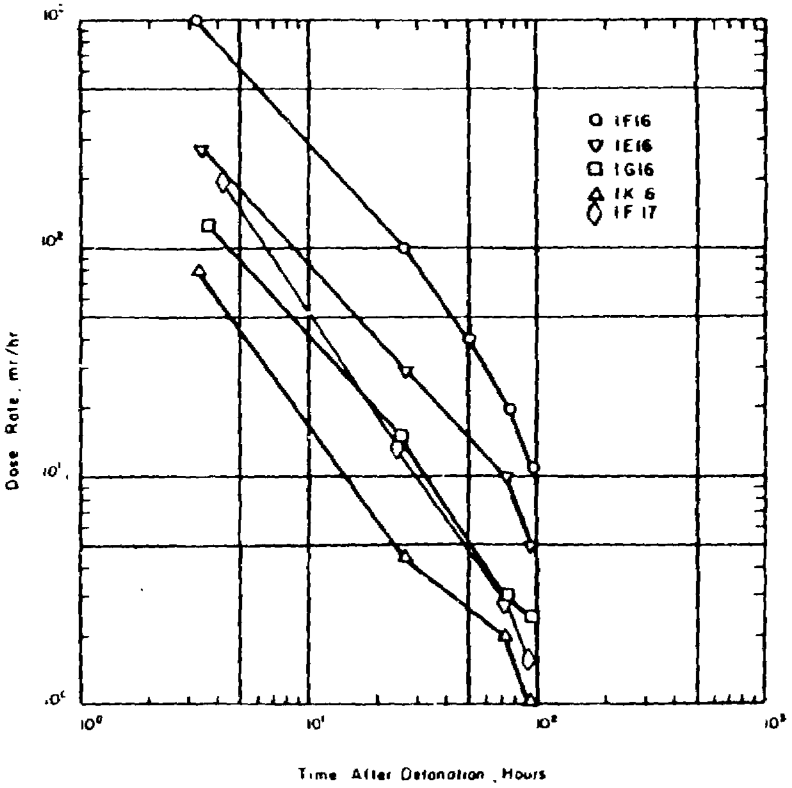

Figure 3.31 Field decay curves for Little Feller I downwind stations.

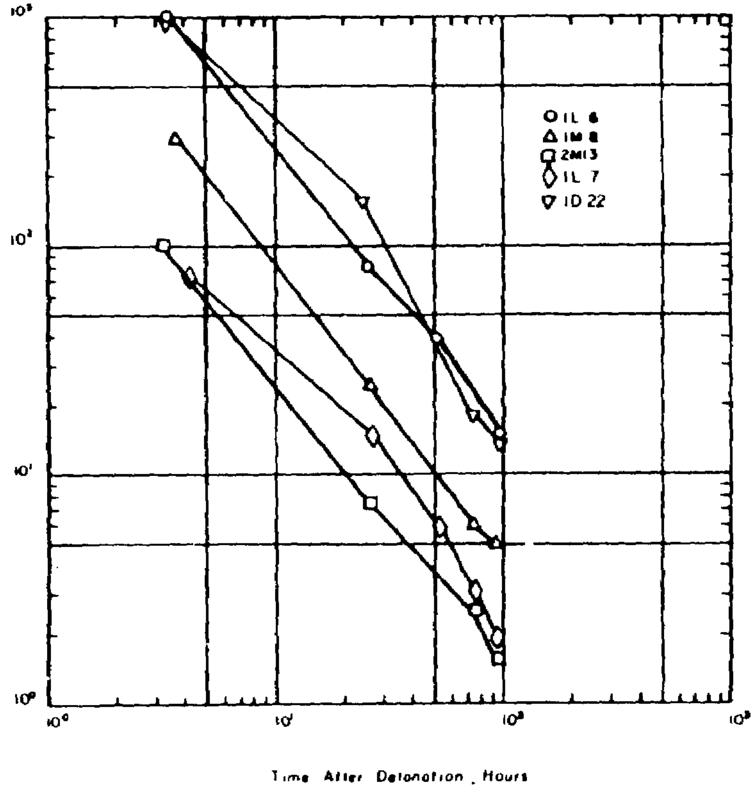

Figure 3.32 Field decay curves for Little Feller I downwind stations

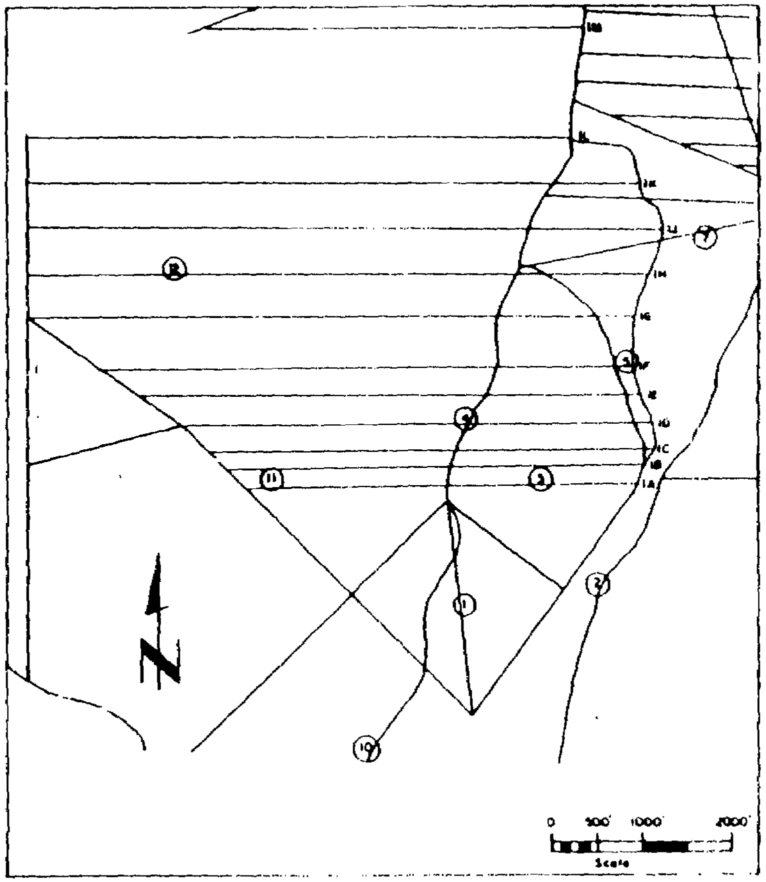

Figure 3.33 Locations of the Little Feller I remote monitoring stations

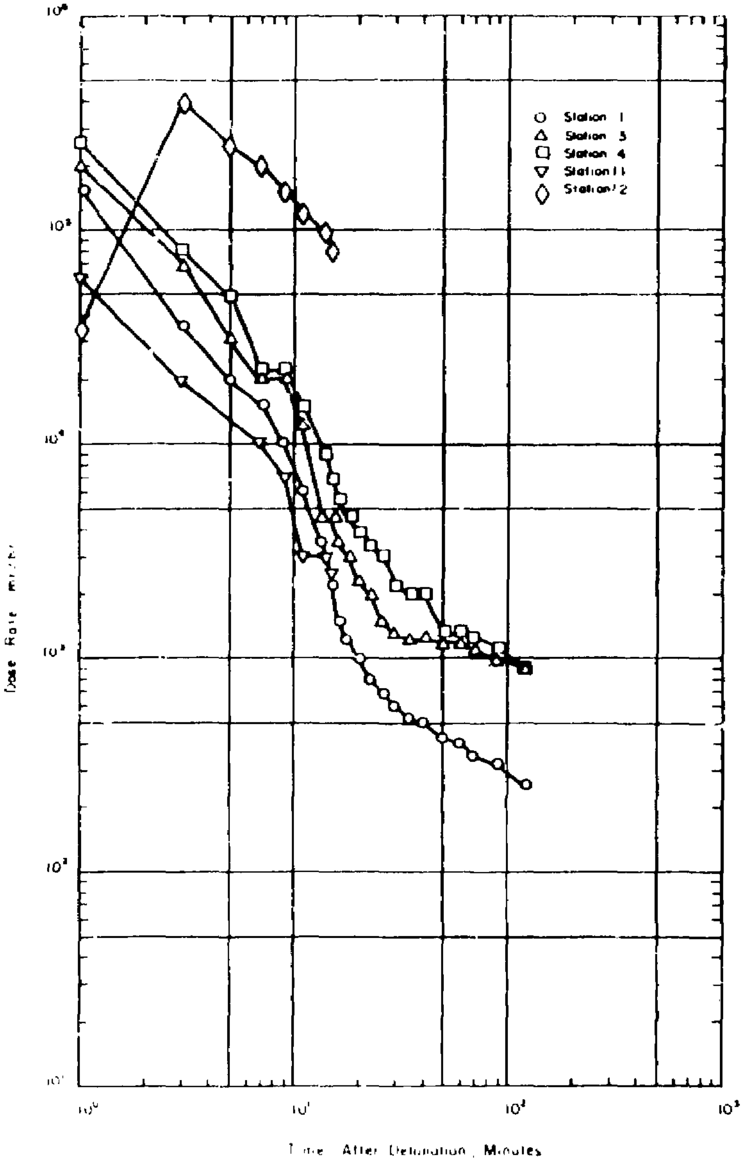

Figure 3.34 Field decay curves for Little Feller I remote monitoring stations

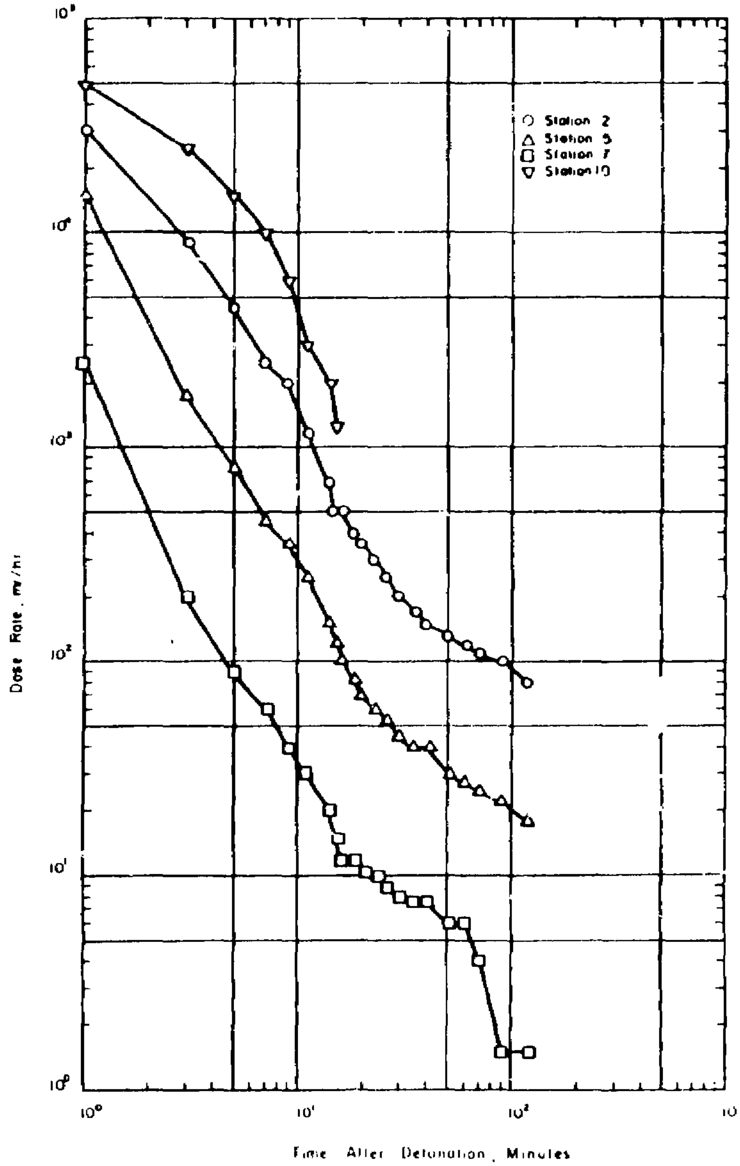

Figure 3.35 Field decay curves for Little Feller I remote monitoring stations

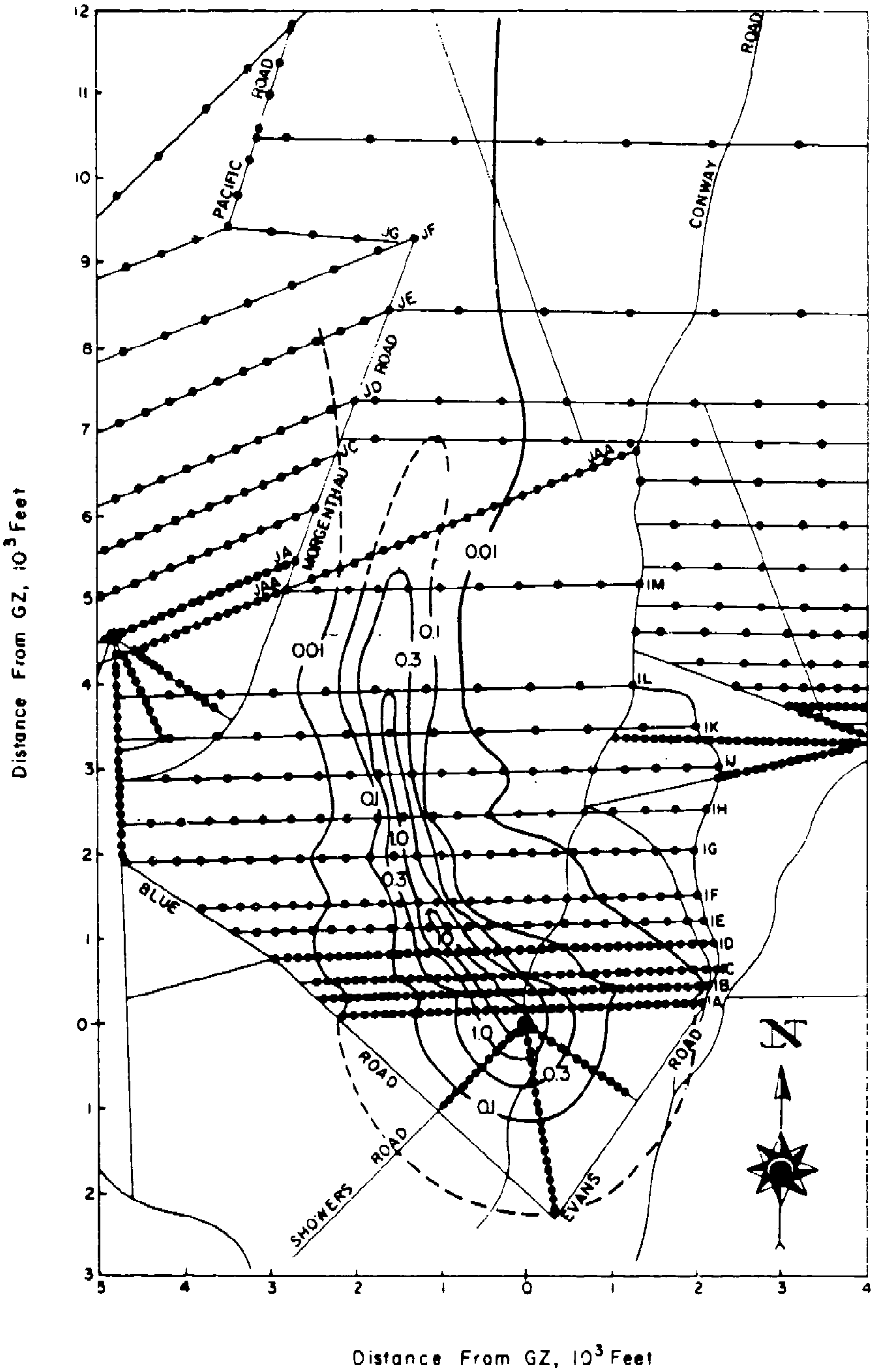

Figure 3.36 Little Feller I dose-rate contours in roentgens per hour at H+4 hours.

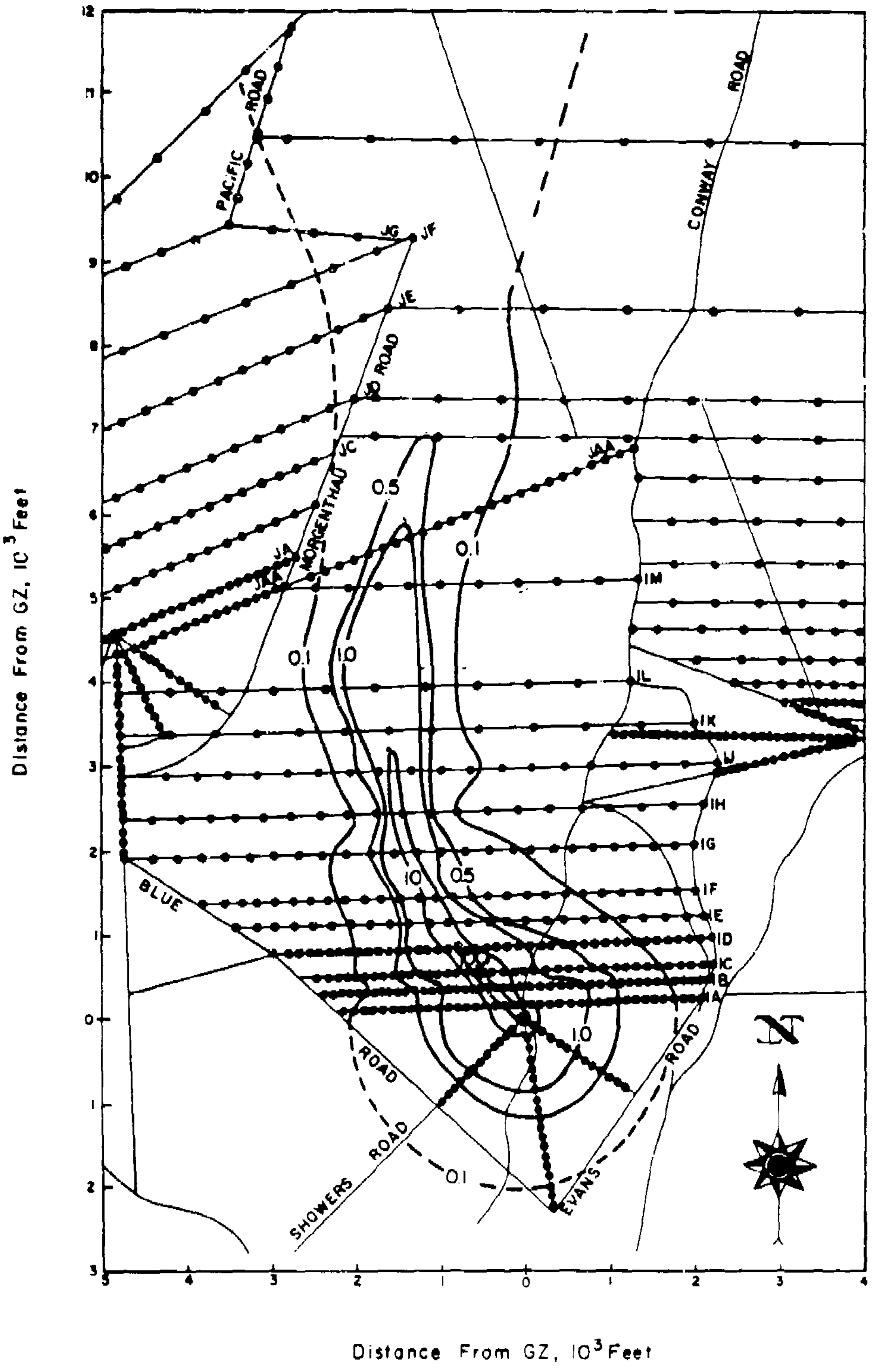

Figure 3.37 Little Feller I dose-rate contours in roentgens per hour at H+1 hour.

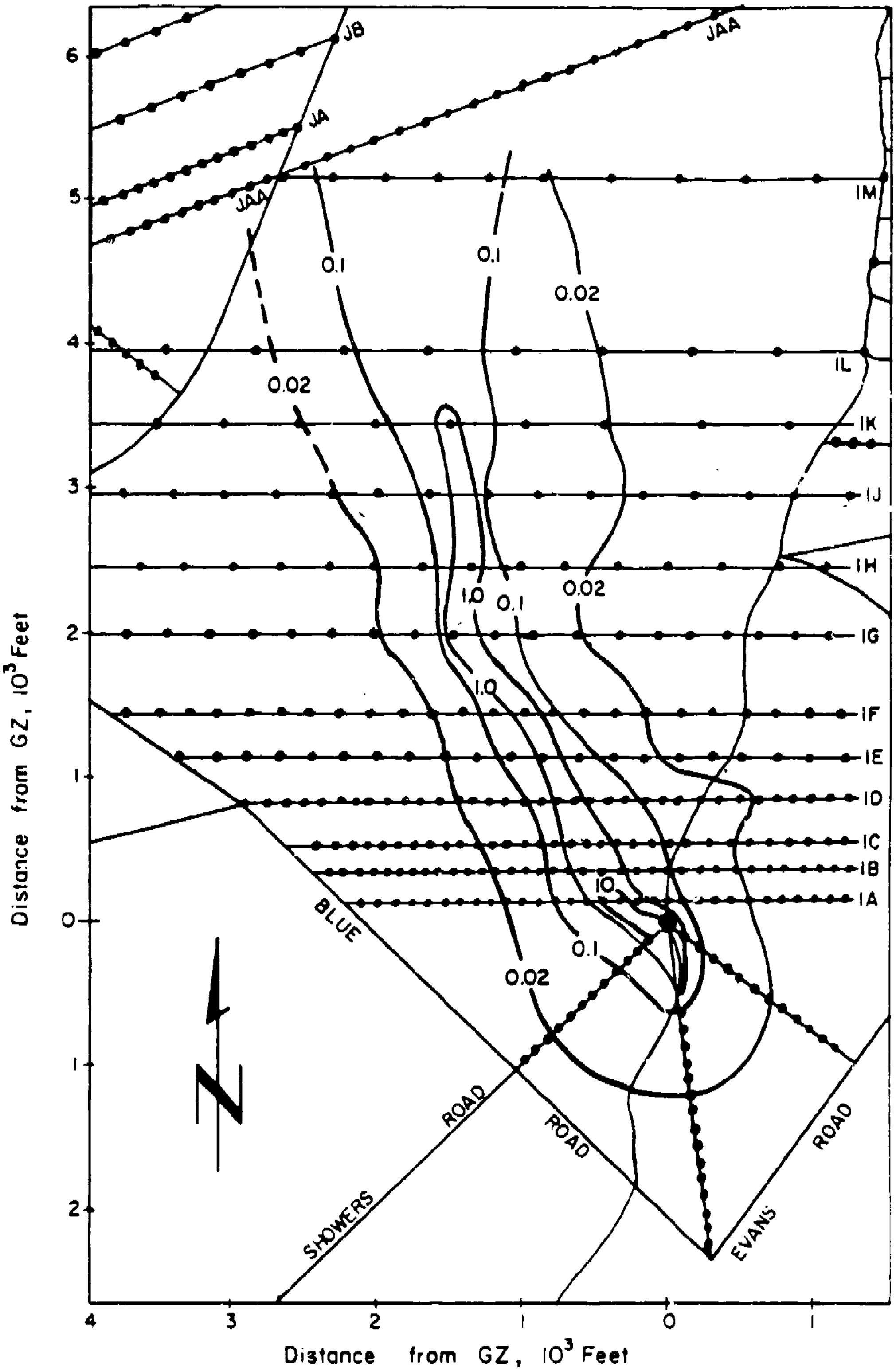

Figure 3.38 Little Feller I dose-rate contours in milliroentgens per hour at D + 98 days.

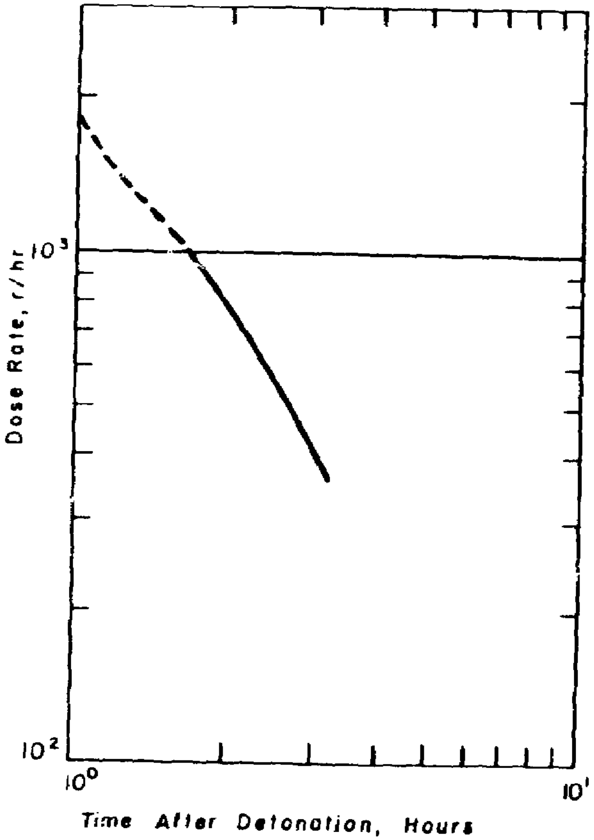

Figure 3.39 Gamma dose-rate decay curve near the Little Feller I crater.

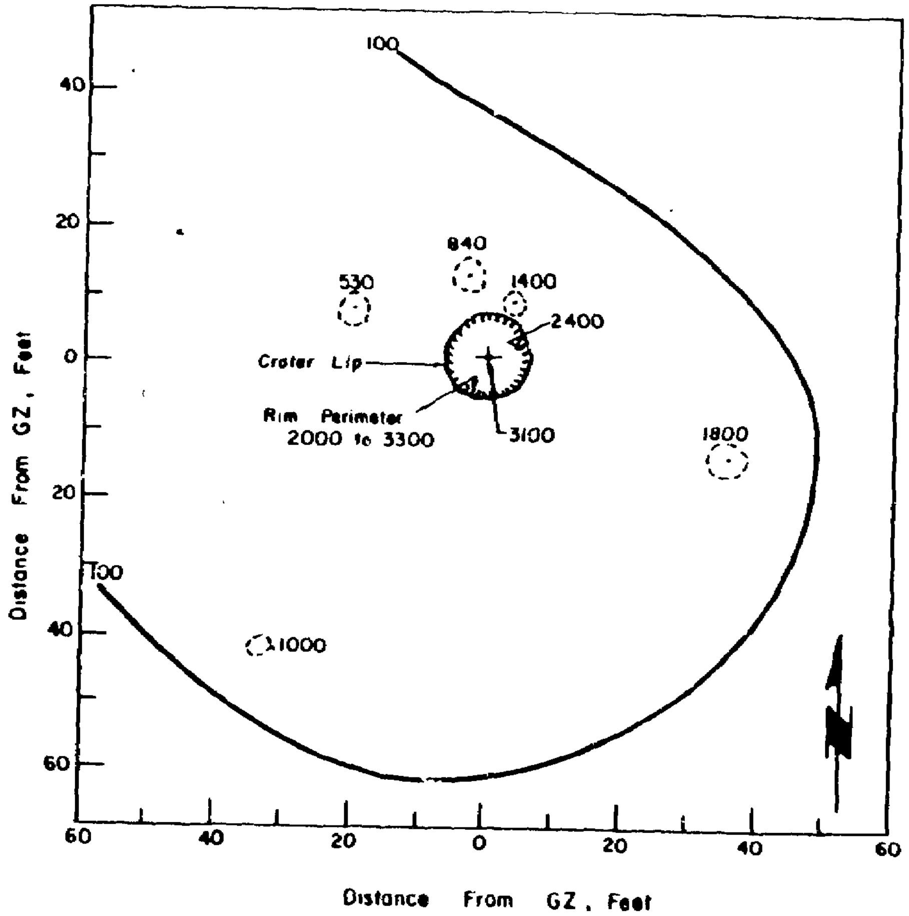

Figure 3.40 Little Feller I ground zero area dose rates in roentgens per hour at H + 1 hour.

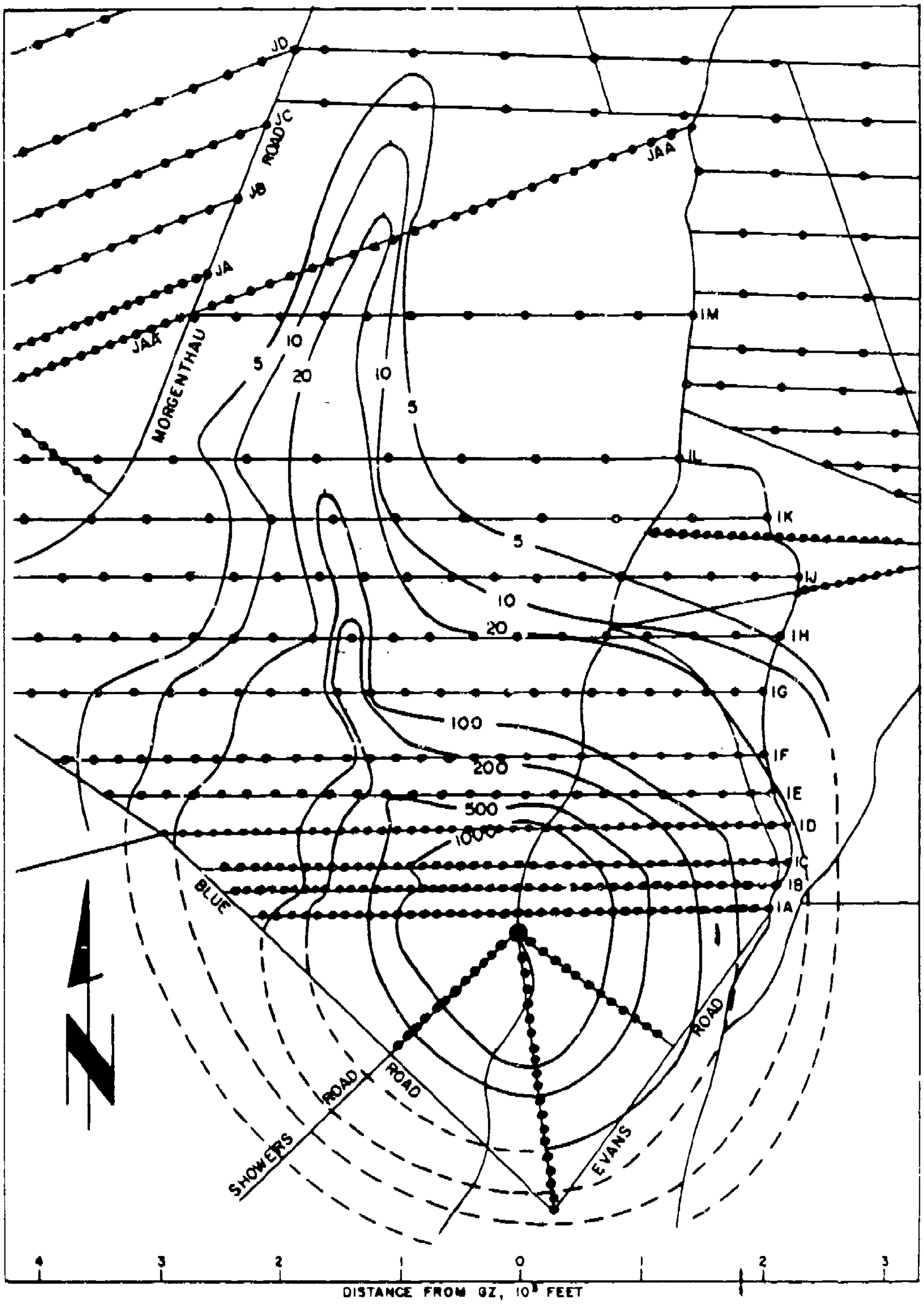

Figure 3.41 Little Feller I 3-day gamma dose contours in roentgens.

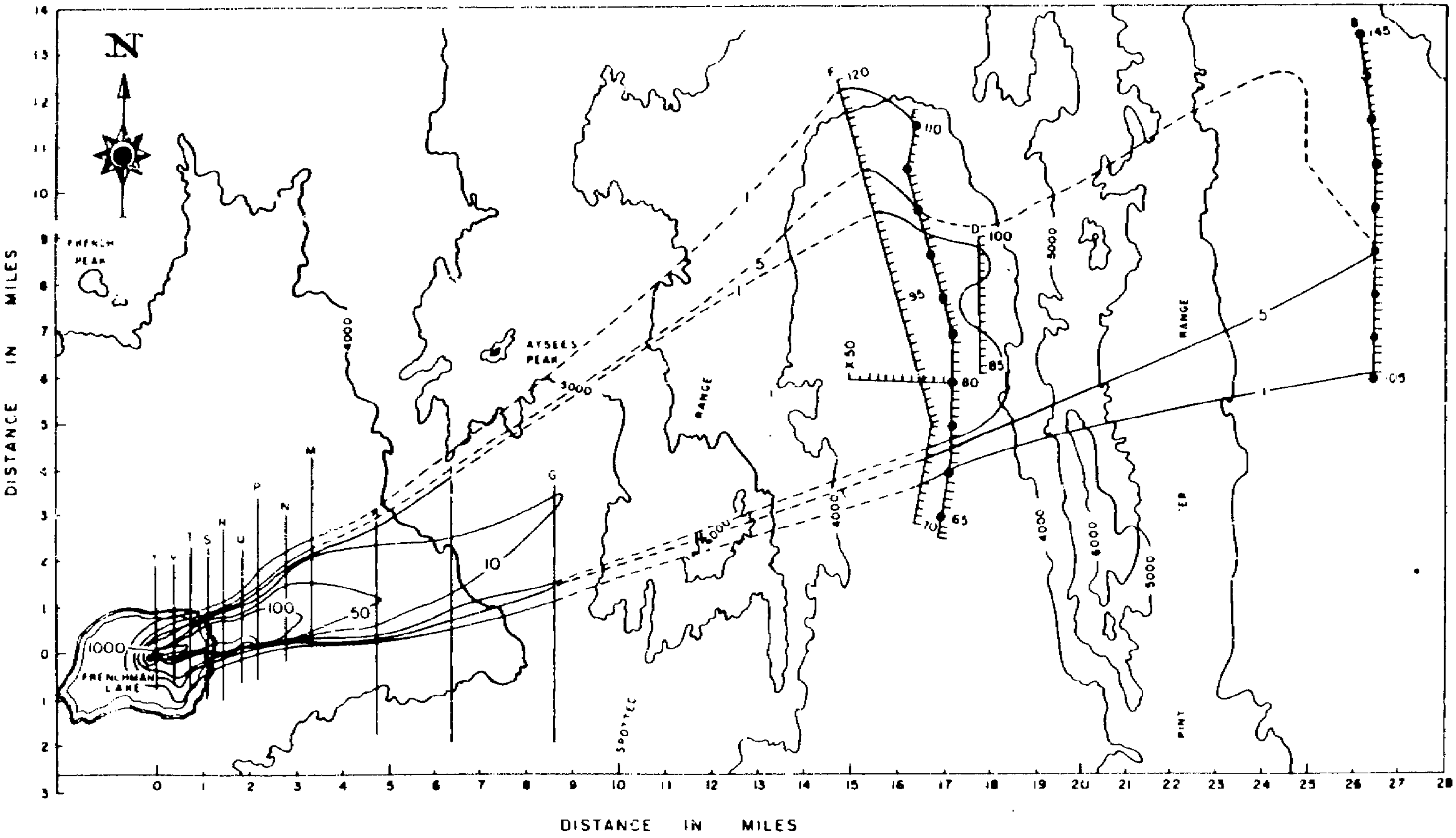

Figure 3.54 Small Boy dose-rate contours in roentgens per hour at H + 1 hour to 27 miles downwind.

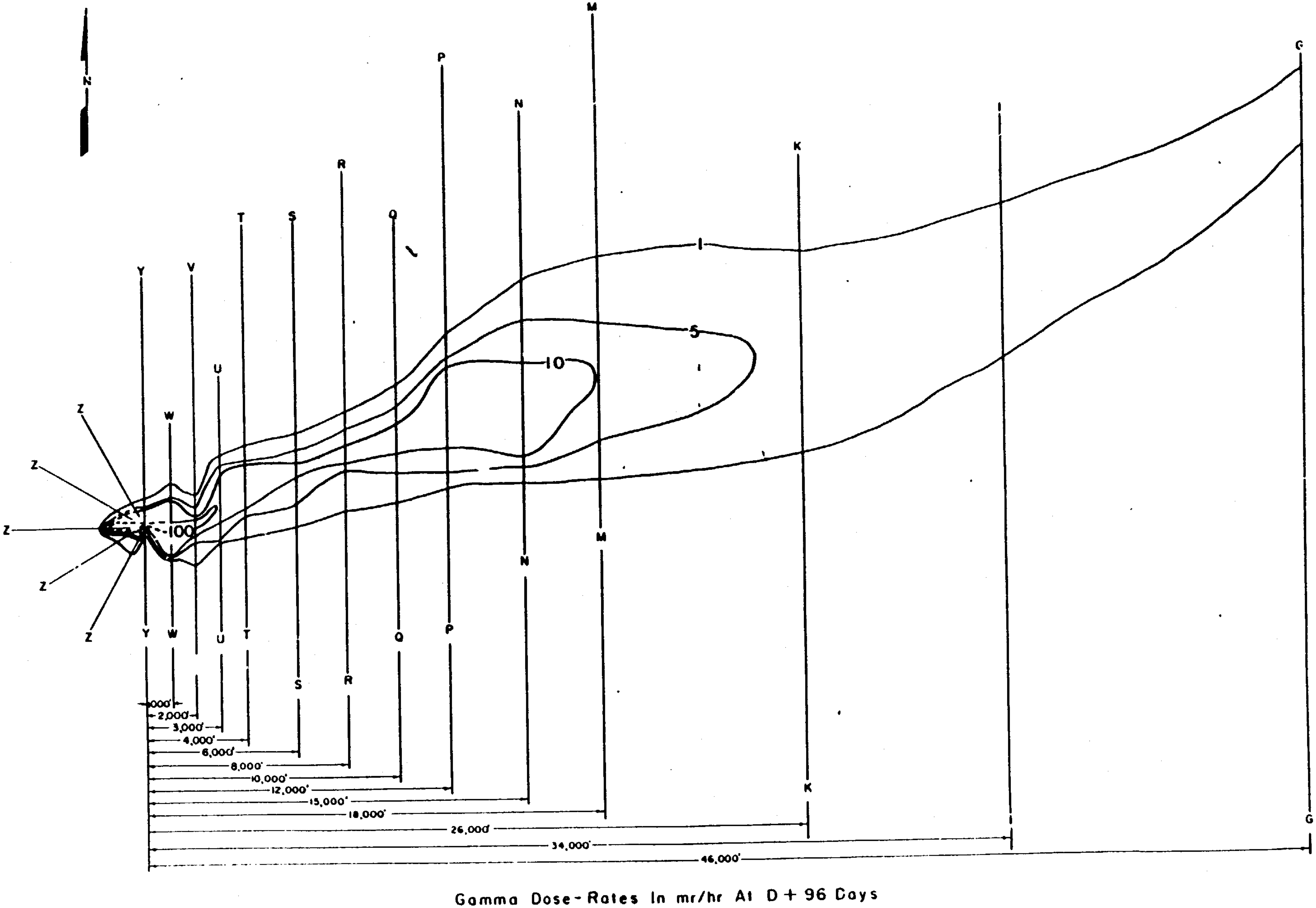

Figure 3.55 Small Boy dose-rate contours in milliroentgens per hour at D + 96 days.

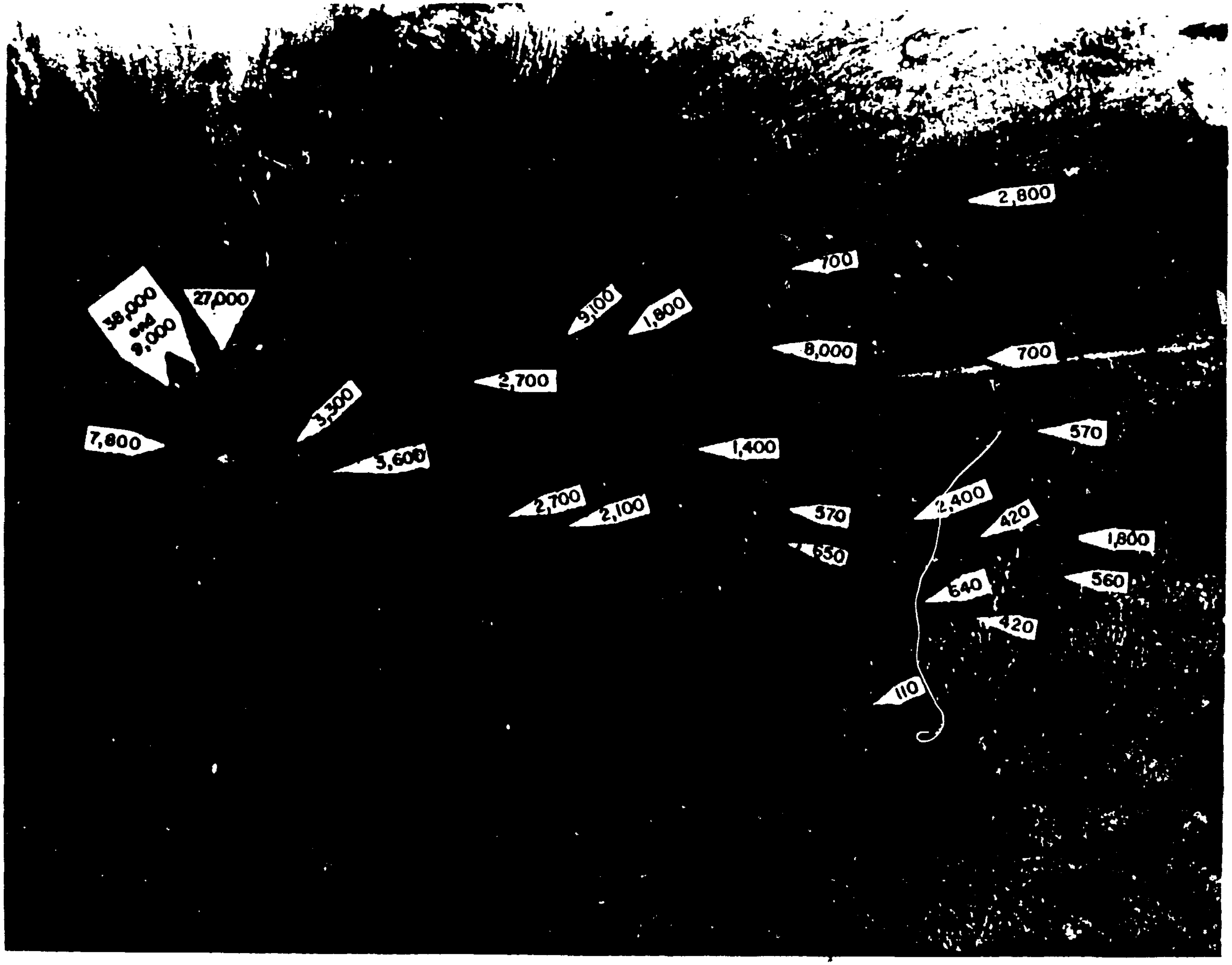

Figure 3.59 Small Boy ground zero area dose rates in roentgens per hour at H+1 hour.

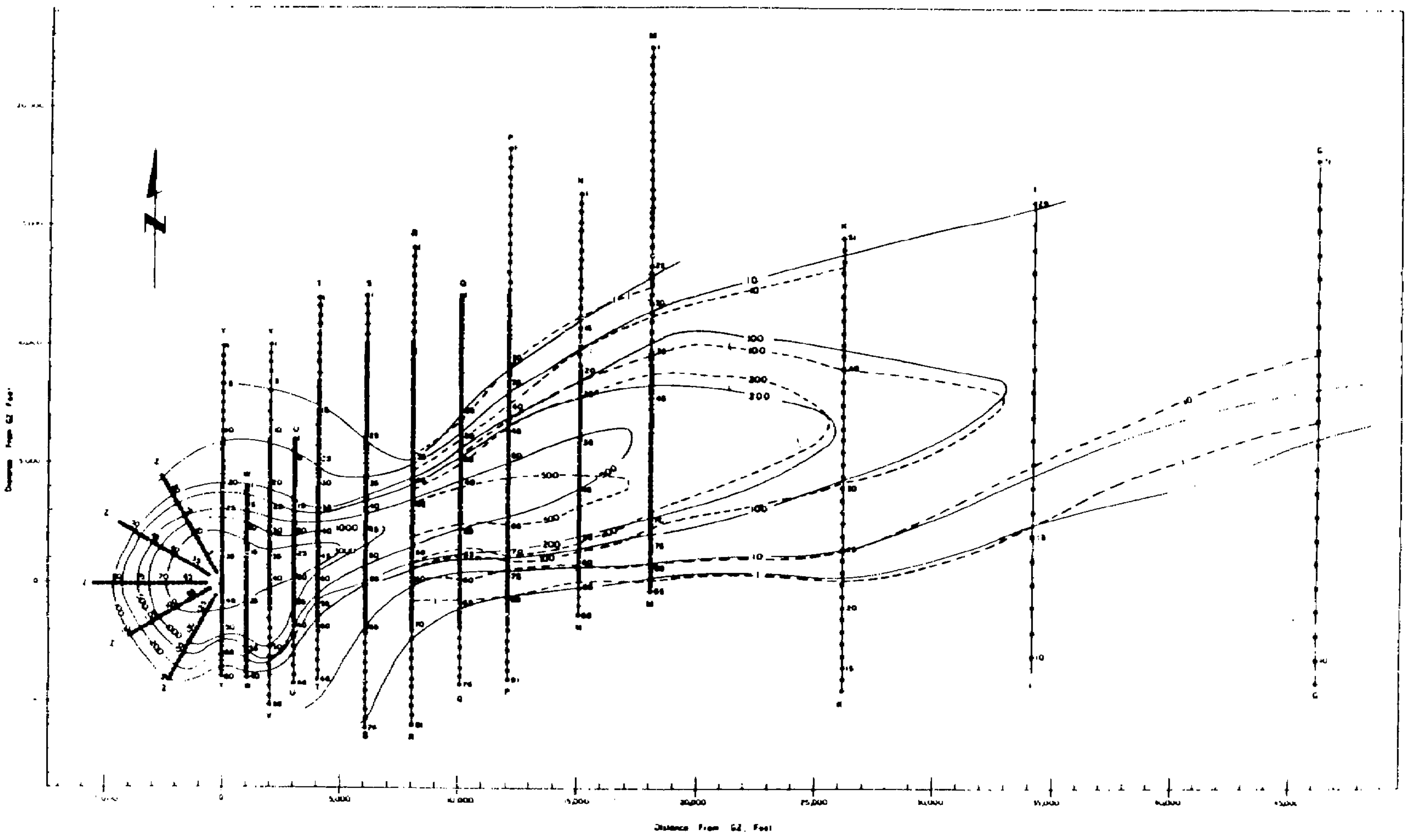

Figure 3.60 Small Boy 4-day gamma dose contours in roentgens to 9 miles downwind.

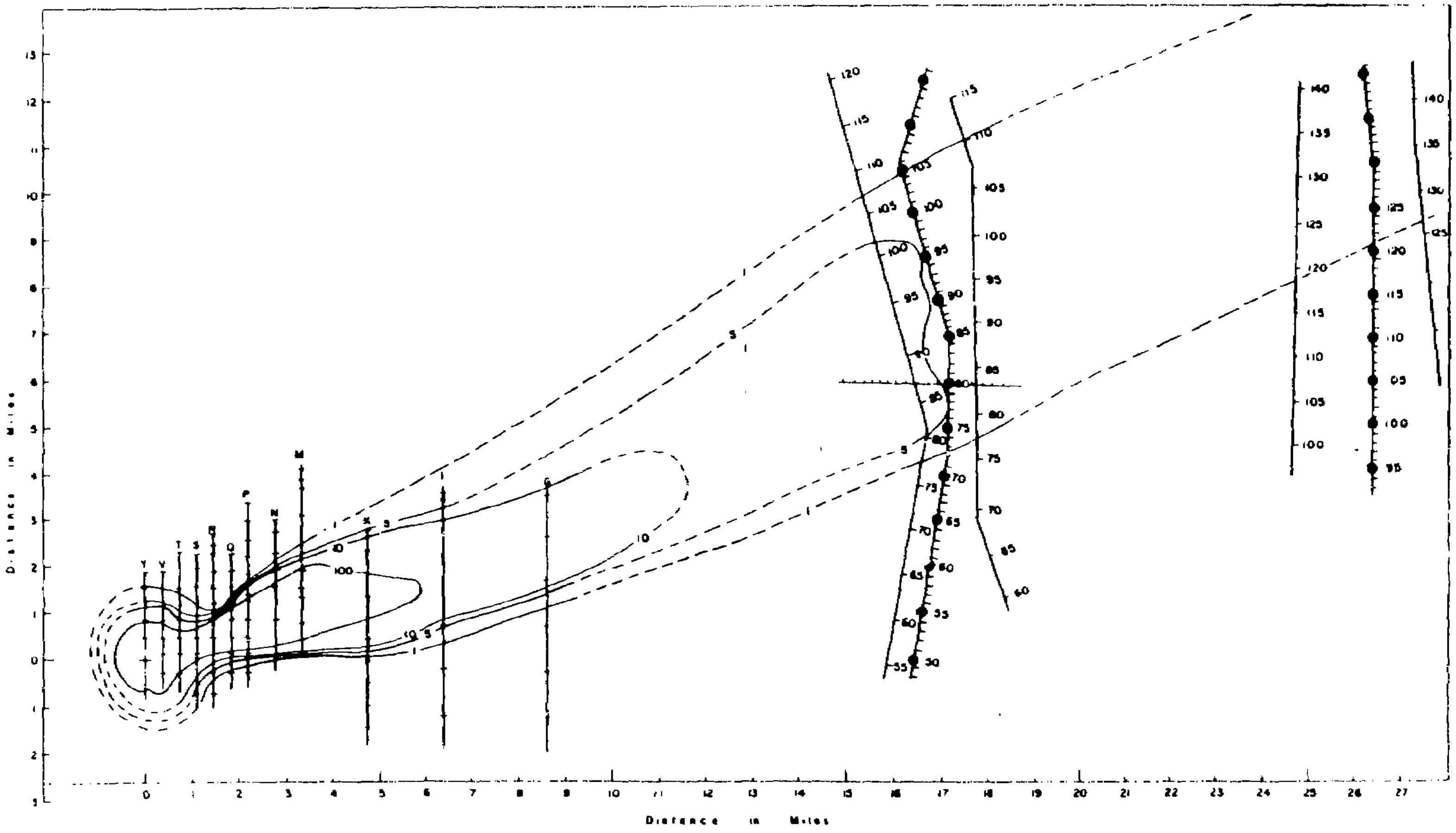

Figure 3.61 Small Boy 4-day gamma dose contours in roentgens to 27 miles downwind

4.2 GROUND ZERO AREA DOSE RATES

The magnitude of the gamma dose rates in the ground zero area showed no consistent variation from point to point in and around the crater. In some instances, dose rates at points relatively close together differed significantly from each other. Although higher dose rates were found within the crater and lip areas than at other locations, individual readings within the crater were sometimes lower than at specific locations away from the crater. All dose rates measured were in areas close enough to ground zero to be influenced by throwout from point of detonation; irregular dose-rate levels could therefore be expected within this area. Although there are indications that crater dose rates increased with yield (within the yield range of the Sun Beam Shots), the different scaled burst heights prevented the determination of definite relationships between crater dose rates and yield.

4.3 PERCENTAGE OF FISSION PRODUCTS DEPOSITED AS CLOSE-IN FALLOUT

The percentage of the fission product activity deposited may be estimated by

$$P = \frac{100S}{D_1 f_f W} \qquad (4.1)$$

where S = the area integral of the 1-hour dose rate over the fallout field being considered

D = the theoretical H+1-hour dose-rate at 3 feet above a smooth infinite plane if all the activity from a 1-kt weapon were spread over 1 square mile. The assumed value is 3,900 $\frac{\text{r-mi}^2}{\text{hr}}$ (Reference 21).

f_1 = the instrument response factor, 0.75 (Reference 21)

f_2 = the assumed terrain shielding factor, 0.7 (Reference 21)

W = yield in kilotons.

S can be calculated as follows:

Let the region $R(I^*)$ be defined as the interior of the I^* r/hr dose-rate contour at H+1 hour. Then the 1-hour dose-rate area integral for $R(I^*)$ is given by

$$S(I^*) = \iint_{R(I^*)} I dxdy \qquad (4.2)$$

If A(I) denotes the area of R(I) and assuming that in the region $R(I^*)$, $I \geq I^*$, Equation 4.2 can be written

$$S(I^*) = I^*A(I^*) + \int_{I^*}^{I_{max}} A(I)dI \qquad (4.3)$$

where $I \geq I^*$.

Upon changing the variable of integration by means of $I = e^u$, the final result for numerical evaluation is

$$\iint_{R(I^*)} I\,dxdy = I^*A(I^*) + \int_{\ln I^*}^{\ln I_{max}} A(u)e^u du \qquad (4.4)$$

or

$$S(I^*) = I^*A(I^*) + \int_{\ln I^*}^{\ln I_{max}} AId\ln I \qquad (4.5)$$

where $I \geq I^*$.

An approximation for the right side of Equation 4.5 can be obtained by determining A for different values of I in a given fallout pattern (Table 4.1 and Figure 4.1) plotting AI versus lnI linearly, connecting the data points by a smooth curve, and finally measuring the area under this curve. The shape of the curve for high values of I together with recorded measurements in and near the crater provide a basis for estimating contributions near I_{max}.

This procedure was followed for all four events, and the results are given in Table 4.2. The percentage of radioactivity accounted for within the Small Boy 0.5 r/hr dose-rate contour was almost four times the percent found within the 0.5 r/hr contours for the two Little Feller shots. Their scaled heights of burst were almost the same. The percentage accounted for within the Johnie Boy pattern (assuming the rated yield) was about three times that accounted for by the Small Boy pattern even though the lowest Johnie Boy dose-rate contour considered was 1 r/hr. The solid line portion of the graph shown in Figure 4.2 has been reproduced from Reference 22 and represents percent activity deposited close-in versus scaled depth of burst.

When the Johnie Boy rated yield is used, the percent activity deposited agrees quite well with the curve originally presented in Reference 22. These four points should be considered to be lower limits because the very low dose-rate contours, below 0.5 r/hr at H+1 hour, were not included in the estimation.

TABLE 4.1 **AREAS** ENCLOSED BY DOSE RATE CONTOURS

Contour Dose Rate, I	Area Within Contour			
	Little Feller I	Little Feller II	Johnie Boy	Small Boy
r/hr	mi^2	mi^2	mi^2	mi^2
0.5	0.33	0.827	-	109.83
1.0	0.208	0.469	33.097	61.63
5.0	-	0.070	-	-
10.0	0.032	0.045	3.924	9.057
20.0	-	0.019	-	-
50.0	-	-	0.536	2.954
100.0	0.00478	0.005	0.214	1.200
200.0	-	-	-	0.285
1,000.0	-	-	0.0917	0.092
2,000.0	-	-	-	0.01665
10,000.0	-	-	0.0161	-
17,000.0	-	-	0.00537	-

4.4 COMPARISON OF OBSERVED AND IDEALIZED CONTOUR PARAMETERS

The observed H+1-hour contour dimensions for each of the four shots were compared with the idealized dose-rate contour parameters as presented in both the 1957 edition and the draft revision of the Department of the Army Technical Manual, TM 23-200, "Capabilities of Atomic Weapons," (References 6 and 23). The draft revision extends the dose-rate contour dimension predictions to lower dose rates and yields than the TM 23-200 now in use. Although none of the four shots was, strictly speaking, a surface shot, no corrections were made since height-of-burst adjustment factors were all close to 1.0. Adjustments of data in the 1957 edition and the draft revision of TM 23-200 for wind velocities were made according to the directions given in each manual. Both the 1957 edition of TM 23-200 and the proposed revision quote reliability values of ±50 percent for all these dimensions.

The dimensions compared are the diameter of the ground zero circle, the downwind distance, and the crosswind distance as defined in the published TM 23-200. The draft revision defined the same dimensions as the ground zero width, the downwind distance, and the maximum width. Shielding factors for terrain roughness were not applied to the draft revision prediction, as suggested in its text. Use of shielding factors generally would have improved the overall predictions of the ground zero widths but not those for the downwind distances of maximum contours widths.

4.4.1 Little Fellers I and II. Ground zero contour widths, downwind distances, and maximum contour widths for the Little Feller shots are shown in Figures 4.3, 4.4, and 4.5.

The effective wind for each of the Little Feller shots was 11.5 knots.

The observed Little Feller I high dose-rate contours (>1 r/hr) extend further downwind but are narrower than the corresponding Little Feller II contours. On the other hand, the observed Little Feller II low-dose-rate contours (≤1 r/hr) extend further downwind and are also wider than the corresponding Little Feller I contours except around the ground zero area. The observed Little Feller I low-dose-rate contours are wider near ground zero. Neither the currently used TM 23-200 nor the draft revision would have correctly predicted the downwind distances of both shots. The areas enclosed by given observed dose-rate contours (Figure 4.1) are slightly greater for Little Feller II than for Little Feller I. This would be expected in view of the slightly higher yield for Little Feller II.

With one exception, the downwind distances of the Little Feller dose-rate contours are greater by factors of 2 to 4 than for the corresponding Fig shot contour distances as shown in Figure 1.1.

4.4.2 Johnie Boy. Observed dose-rate contour dimensions for Johnie Boy are compared with the TM 23-200 data in Figures 4.6, 4.7, and 4.8.

Observed and idealized contour widths agree quite well, both in the ground zero area and downwind of ground zero. The observed downwind distances are generally greater than those predicted by either version of TM 23-200. There is some uncertainty about the proper downwind distance to use for the 100-r/hr contour because of the hot spot observed at approximately 1.7 miles from ground zero (See Figure 3.20). If this distance is used, a relatively smooth curve is obtained (Figure 4.8). These downwind distances are outside the 50 percent reliability of the draft revision for the entire range from 1 to 10,000 r/hr and also outside the reliability range for the currently used manual in the 100 to 10,000 r/hr range. It is recognized, however, that a detonation at the Johnie Boy scaled depth would be expected to produce somewhat more local fallout than would a surface shot.

4.4.3 Small Boy. Comparison of the Small Boy observed contour dimensions with TM 23-200 data is shown in Figures 4.9, 4.10, and 4.11. The effective wind for Small Boy was 6 knots over the area of the on-site pattern. The curves in the figures which are based upon the revised TM 23-200 data are for 10-knot winds since no procedure is given for correction to wind speeds lower than 10 knots.

The actual widths of the ground zero contours are smaller than those predicted by TM 23-200 for a surface shot, but the maximum widths of downwind distances agree generally within 50 percent with the revised TM 23-200 data. If correction of the data for scaled burst height and also for the lower effective winds had been made, poorer agreement would have resulted between the observed and the predicted downwind distances.

4.5 COMPARISON OF JOHNIE BOY AND SMALL BOY FALLOUT PATTERNS WITH FORD INSTRUMENT COMPANY PREDICTIONS

Fallout predictions for Johnie Boy and Small Boy were made by the Ford Instrument Company under a contractual arrangement with USANDL (Reference 24). Project 2.8 personnel relayed shot-time wind data by telephone to Ford Instrument Company offices in Long Island City, New York. These data were processed onto punched cards and the predictions computed. Points describing the contours were converted to Army Map coordinates and relayed back to NTS by telephone.

The Ford Instrument Company fallout model is based on the stabilized cloud concept and covers the yield range from 0.1 to 100 Mt. The stabilized cloud and stem are divided into wafers that are then traced to locations on the ground. Since each wafer has associated with it an H+1-hour dose rate, the summation produced an H+1-hour dose rate for every square of the grid. Contours are then constructed by hand, based upon the dose rates assigned to the grids. A more detailed description of this system may be found in Reference 24.

A comparison of the Johnie Boy prediction with the observed pattern is shown in Figure 4.12. The prediction was based upon winds at shot time, 0945 hours PDT, and the detonation was treated as a surface burst. A yield of 0.5 kt was assumed. The predicted and measured close-in fallout patterns for this shot are in general agreement both in direction and distance. For distances greater than those shown in Figure 4.12, however, the predicted 1 r/hr contour went much further toward the east than did the observed contour (See Reference 24).

The Small Boy predicted pattern is compared with the observed pattern in Figure 4.13. For this prediction,

and wind data as reported for 1135 PDT (H+4 minutes) were used. In this case, the predicted distances for the high dose-rate contours were too small and, for the lower dose-rate contours, were too large. The general directions of the contours agreed very well.

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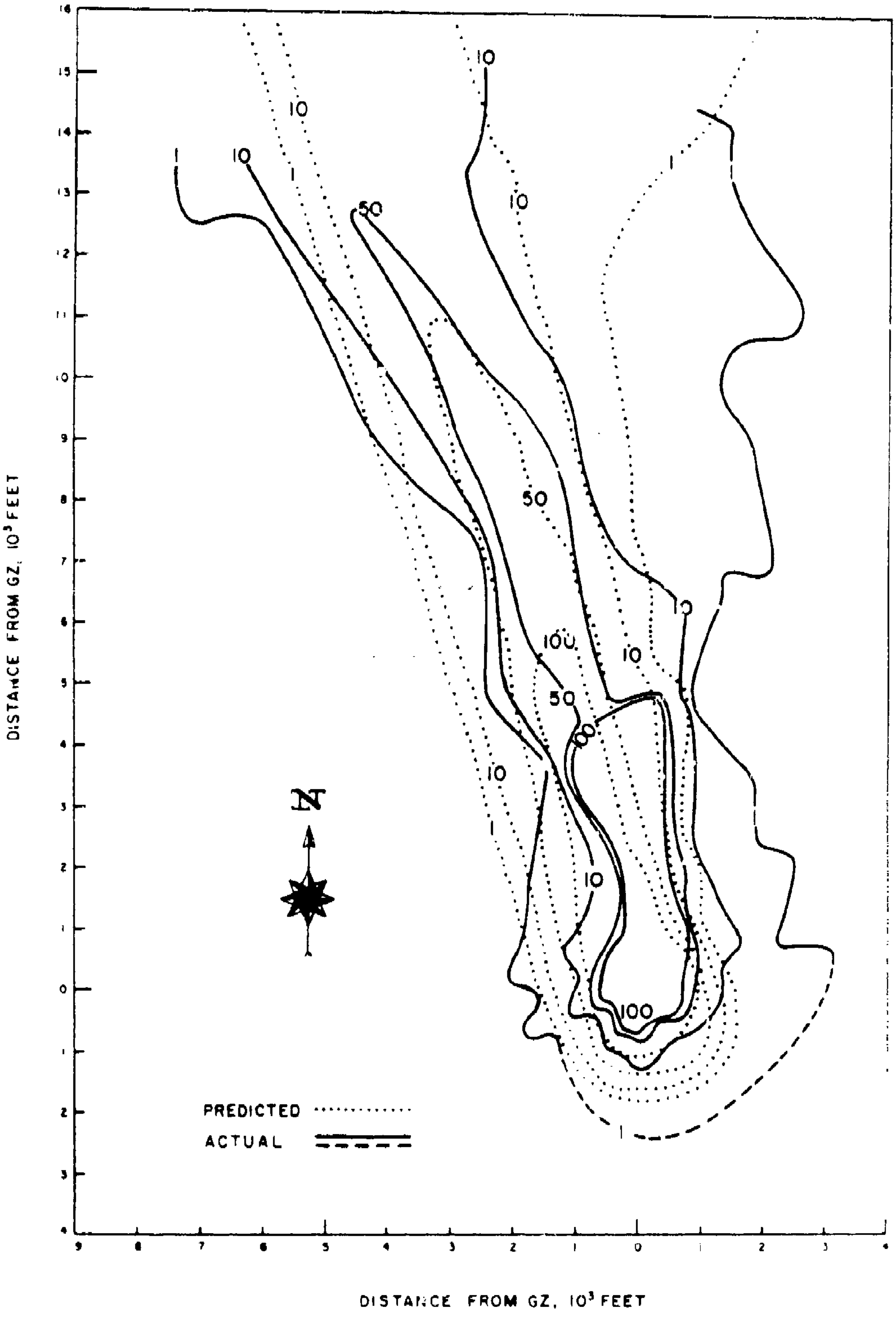

Figure 4.12 Comparison of Ford Instrument Company prediction with observed Johnie Boy pattern.

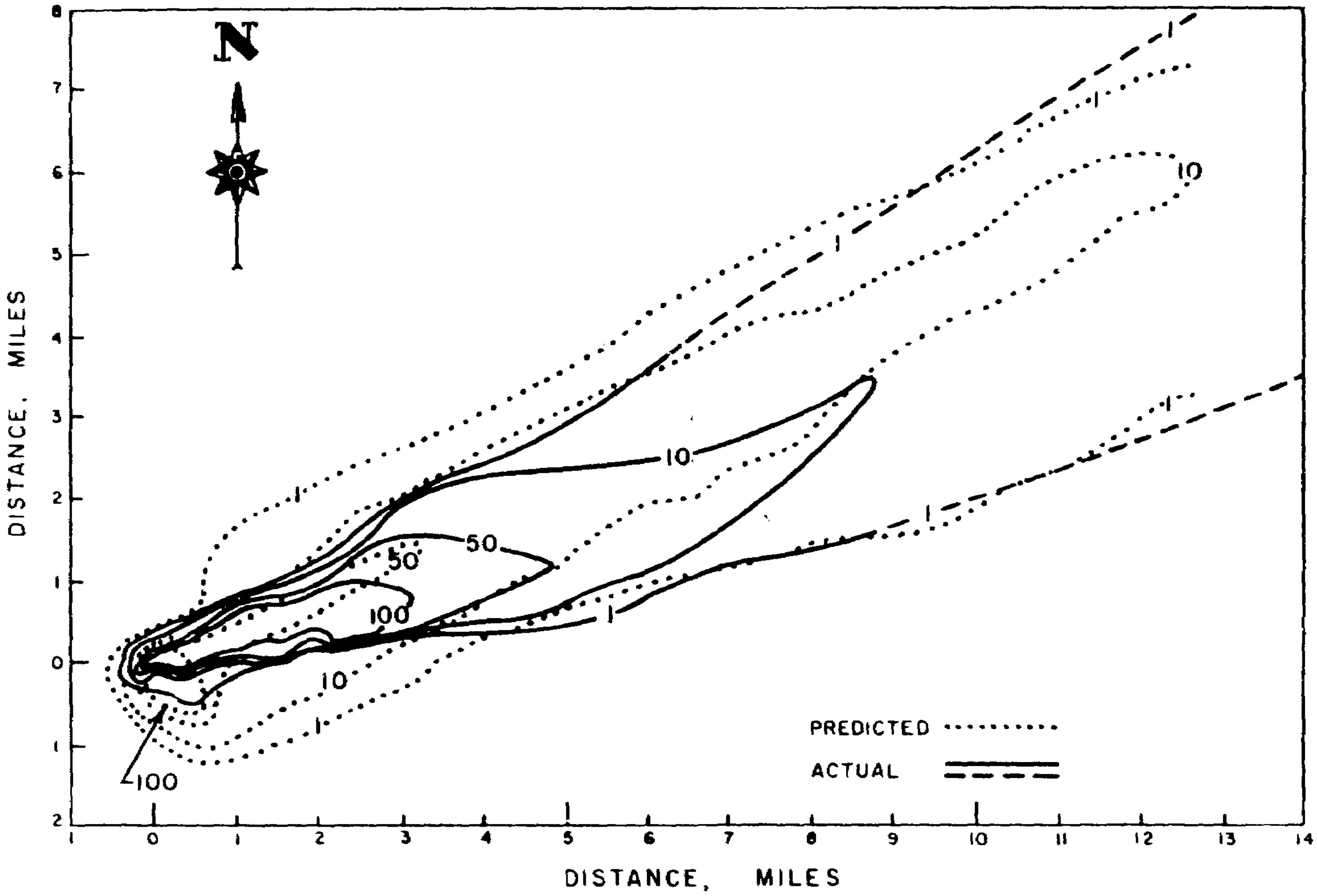

Figure 4.13 Comparison of Ford Instrument Company prediction with observed Small Boy pattern.

CHAPTER 5

CONCLUSIONS

The H+1-hour gamma dose-rate contours for the Little Feller I and II, Johnie Boy, and Small Boy shots are based on ground surveys that were significantly more detailed than surveys at any previous nuclear test. The reliability of the contours presented is limited only by the degree of accessibility of the terrain, the accuracy of the instrumentation used, and the derived field decay rates.

Field gamma dose-rate decays through D+1 day varied considerably from point to point within individual patterns. In general, for the above-ground shots, there were differences between the decay rates near ground zero and those observed in the downwind direction. In the expression $I=I_a t^{-\wedge}$, the average exponent in the upwind and cross-wind directions tended to be appreciably less than 1.2; for stations at significant downwind distances, the decay exponent tended to be near 1.2.

The maximum ground zero dose rates based on measurements extrapolated to H+1 hour ranged from 3,300 r/hr for the Little Feller shots to 38,000 r/hr for Small Boy.

The total gamma dose contours based upon film badge measurements show the influence of initial gamma radiation in the ground zero area. For Small Boy, the close-in downwind total-dose contours beyond the range of initial gamma radiation compare well with total-dose contours calculated from the H+1-hour dose rates when estimated fallout arrival times are used.

The percent of total activity deposited by Little Feller I, Little Feller II, and Small Boy within the 0.5 r/hr H+1-hour contour was 6.5 percent, 6.6 percent, and 24 percent, respectively. The percent deposited within the Johnie Boy 1 r/hr H+1-hour contour was 69 percent.